THE TEACHING OF NATURE STUDY

AGENTS

AMERICA	THE MACMILLAN COMPANY 60 FIFTH AVENUE, NEW YORK
AUSTRALASIA . . .	OXFORD UNIVERSITY PRESS 205 FLINDERS LANE, MELBOURNE
CANADA	THE MACMILLAN COMPANY OF CANADA, LTD. ST. MARTIN'S HOUSE, 70 BOND STREET, TORONTO, 2
INDIA	MACMILLAN AND COMPANY, LTD. 270 HORNBY ROAD, BOMBAY 294 BOW BAZAR STREET, CALCUTTA NORTH BEACH ROAD, MADRAS

THE TEACHING OF NATURE STUDY

BY

C. VON WYSS

FELLOW OF THE "LINNÆAN SOCIETY"
LECTURER IN THE LONDON DAY TRAINING COLLEGE, UNIVERSITY OF LONDON
AND RECOGNISED TEACHER IN THE UNIVERSITY

WITH A PREFACE BY

T. PERCY NUNN, M.A., D.Sc.,
PROFESSOR OF EDUCATION IN THE UNIVERSITY OF LONDON

A. & C. BLACK, LTD.
4, 5 & 6 SOHO SQUARE, LONDON, W. 1
1927

Printed in Great Britain

PREFACE

By T. Percy Nunn, M.A., D.Sc.,
Professor of Education in the University of London.

Miss von Wyss has asked me to contribute a preface to her book; and though her work assuredly needs no introduction or commendation from another, I have felt unable to decline the invitation. For it is an honour to have one's name connected, even undeservedly, with the writings of a colleague who, as so many generations of her students could testify, is an inspired teacher of nature study and an inspiring teacher of teachers.

In a companion volume Miss von Wyss has shown that she belongs to the happily gifted company of people who enjoy what, to the envious outsider, seems an almost wholly mysterious intimacy with the creatures of field and wood, of pond, burrow and air; and also that, like a select few of that company, she has the literary artistry which lends duller eyes power to see and to delight in what they could never have discerned by themselves. In the present book she addresses those who are teachers by vocation and nature-lovers by grace, and seeks to show them how the loving and disciplined study of nature may be made to play its proper and unique part in the well-rounded growth of young minds. It cannot be denied that such a work is needed. For although much has been written and said about the value of nature study, the subject has not been altogether fortunate in its advocates. It is, therefore, not unimportant that a teacher of great experience, who combines in a singular degree the knowledge and objectivity of a trained naturalist with insight into the movements and reactions of children's minds,

should set down in a manner so clear and delightful, so philosophical and so practical, the things it is most desirable for the tyro and the less well-versed teacher to know.

Elsewhere, plagiarising a famous phrase of the philosopher Spinoza, I have urged that the study of science, if it is to have its full value as an educational instrument, must be rooted in "the intellectual love of nature." Miss von Wyss's pedagogy seems to me to be sound and fruitful largely because she appreciates so clearly the truth that aphorism is meant to convey. Thus she holds, I think rightly, that the teaching of the biological—and to a scarcely less extent the physical—sciences is likely to be most effective if the relatively abstract interests they represent grow out of a deeper and more concrete interest in the interlocked ways of open-air nature, living and inanimate; and, correspondingly, that a child's response to the delightful revelations of the ways of nature should from the first be intellectualised, and so be made to point forward to the fully scientific activity which ought at length to emerge from it. And allied to this view is her belief that biological teaching, based on nature study as nature study is here conceived, may be a means of giving boys and girls dynamic ideals, drawing their force from objective and accurate knowledge, which may do much to refine and keep wholesome the quality of their own lives. These are questions of great educational interest and social importance with which Miss von Wyss is led incidentally to deal in the book that it is my privilege to commend to the students and teachers to whom it is more specially addressed.

April, 1927.

AUTHOR'S PREFACE

IT is hoped that this book may be of some use to teachers of nature study when, having given descriptive nature lessons for some time, they have come to ask themselves the question, And to what end? I have attempted to show the inner meaning of nature study, its relation to human life, and its characteristic point of view and method. I have abstained from giving outlines of lessons, believing that the teacher must study nature first-hand, consulting suitable books for guidance, and that the lesson itself must arise from the teacher's interest and the children's spontaneous response. It cannot, therefore, be prepared by any other person.

I have to thank Professor T. P. Nunn for his inspiring guidance in the general theory of education. His teaching has thrown light on every phase of nature study, and established my faith in its value. I also wish to thank the School Nature Study Union for permission to include portions of some leaflets published by them.

I am indebted to Miss B. E. Mackie for valuable assistance and for correction of proof sheets.

As a member of the staff of the London Day Training College (University of London), I am an official of the London County Council, but the Council accepts no responsibility for any opinions or conclusions expressed in this book.

C. VON WYSS.

CONTENTS

SECTION I

THE THEORY OF NATURE STUDY

SECTION II

THE TEACHING OF NATURE STUDY

SECTION III

AIDS TO NATURE STUDY

THE TEACHING OF NATURE STUDY

SECTION I

THE THEORY OF NATURE STUDY

I. THE MEANING OF NATURE STUDY

NATURE study is as old as the hills, or at least as old as human thinking. Man has ever studied nature from necessity.

To a child born in this world, as to the human race in its infancy, "the world is so new and all." A conscious outgoing of the mind towards the environment, and the acquisition of intellectual control over it, alone ensure efficiency and happy, healthy living. This environment is largely represented by the world of nature which obtrudes itself into all human existence, and is an integral part of, and a powerful agency in, human life.

In ancient days success in finding food, adequate shelter, covering, and safety, required a close study of Nature and of her manifold changes. The habits of watching, of making discoveries, of reasoning from facts, of observing and estimating their significance, are habits based on instincts of self-assertion, of self-preservation, and on immediate necessity. They have persisted through countless generations, and have now become part and parcel of the equipment of normal human minds.

Although in the present day the affairs of life have become for most people infinitely more complex and are not so directly concerned with finding and cultivating the fruits of the earth, or the chasing and training of wild creatures, or the building of safe habitations amid hostile natural forces, yet

to be observant, to reason, and to interpret are as much as ever vital mental processes essential to human progress.

This general response to the stimulus of environment in its earliest phases is organic and biological. The tendency to search for meaning, the instinct for acquisition, intellectual and material, become effective most readily in the presence of the simple phenomena of physical and biological nature. It is therefore claimed that free intercourse with nature will ensure normal development of the functions of observation and inductive reasoning. Not only are the facts of nature directly accessible to the young mind, but since the business of life of animals and plants is simple and unobscured it is allied to that of the child, and there is a subtle kinship and a sympathetic relationship between him and his friends in the animal and plant world which quicken understanding and foster intimate intercourse.

Since, then, nature makes a strong appeal to the mind of the child, stimulating his curiosity and sense of wonder, he in his turn experiences a joyousness of observation which is the very foundation of a naturalist's equipment and will make life richer whether he becomes a scientist or not.

Intelligent intercourse with nature, and direct experience, constitute nature study, and are the beginning of one of the main roads of human progress. Nevertheless, we hear it said that nature study is a "new subject," but recently introduced into educational systems and still looked at askance by the more conservative members of the teaching profession. It is not difficult to reconcile the two statements. Although nature study, being the human mode of approach to the wonders and secrets of nature, has existed since the beginning of days, yet it is but a generation since the purely humanistic studies of the school curriculum have in part been replaced by realistic and practical pursuits. With the introduction of science into schools, nature study has made its entry. Such study of nature, within the four walls of a class-

room, for periods fixed as regards point of time and duration, and controlled by minds trained to order and method, tended to become less spontaneous and more formal. In recent years, however, education has been characterized by greater freedom and greater appreciation of individual claims and efforts, and consequently the nature study of the classrooms is approximating more nearly the general human response to the ways of nature. Moreover, it is realized that nature study, providing, as it does, opportunity for the practical study of the various aspects of life, forms a rational foundation for individual and social well-being.

There is little doubt but that the study of nature will occupy a prominent place in schemes of education which a newly awakened people will demand for the coming generations. Loftier conceptions of freedom and individuality will claim a more liberal education and an opportunity for the free play of all the human tendencies that have ever made for progress.

II. RELATION OF NATURE STUDY TO SCIENCE

It is interesting at this stage to determine the relation between nature study and "science." Inasmuch as nature study claims to be a conscious outgoing of the mind, a conative process in the direction of such objective realities as are implied by the word "nature" with the definite purpose of finding meaning and making it intelligible, it shares the general function of science.

The spirit of enquiry, whether of the individual or of the race in its youth, addresses itself to any order of phenomena as chance and necessity may dictate, and is unrestricted in its choice of material. In the course of progress and change,

interests become specialized and the regions of enquiry more and more restricted. Thus the various sciences arise. The natural sciences are all specialized forms of nature study, and the latter is organically the earliest and undifferentiated phase of all science. But this is not the only relation. The spirit of enquiry in its infancy goes by the name of instinct of curiosity. The little child is impelled, for no reason plain to him, to take a toy to pieces, or to disturb an ant-heap with a stick. He is not guided by reason in his action; it is only by degrees that such instinctive behaviour gives rise to rational conduct. Nature study is characterized by a predominance of instinctive reactions, which gradually give way to the function of reasoning, preparing the way for science. The children's curiosity is rarely a purely intellectual endeavour, their attitude towards the world of nature being generally accompanied by vivid emotions. A feeling of wonder, awe, or fear suffuses their mind in the presence of new discoveries, often affecting judgment and distorting vision. Nature study, therefore, besides being unrestricted in the choice of material, making the world and all that therein is its own, is not a purely intellectual process, but reveals instinctive and emotional elements. Gradually the lamp of reason begins to shed its clear light and science develops from the nature lore of the child in a direct line of descent. Interest in the world around becomes more and more sustained as it becomes evident that the discoveries are not only wonderful and delightful but actually useful. That you can make candles with rushes, a squirt with the stalk of cow parsnip, chains fit for kings and queens with daisies and rose-hips, toys from chestnuts and acorns; that, besides nuts and many berries, rhizomes of polypody and leaves of sorrel are good to eat; that you can cure warts with the latex of celandine and nettle-stings with dock leaves; that you can make bows and slings of hazel and arrows of spindle wood; or can tell who likes butter by means of a buttercup and the

time of the day by the help of a dandelion clock; that the hazel will tell you where gold and silver and good water are hidden in the ground; that you can do a miracle with an ant-heap and a wonder with a dandelion stalk—all these discoveries mark a crossing of the borderland between the region of general and random study of nature and the realm of exact science. Children's disinterested desire to know and understand the world around them for its own sake, to view it as it is, becomes the motive for investigation and for all further intellectual activity, and pure science is the result. Thus we see that science changes as it develops from nature study. Not only does it become the specialized study of the different orders of phenomena, but it also assumes a different outlook and motive. The transition from the one to the other is a gradual growth.

Science, having passed through the stages of instinctive observation and of reasoned inference, proceeds yet further, and is merged at last in that speculative philosophy towards which all intellectual pursuits tend. In their attitude towards nature the child and the philosopher are alike in this, that they view as a whole the tapestry of creation; but the picture for each is different, for, by a process of analysis, science has singled out the warp and the woof and in synthesis has set forth a new meaning, which the philosopher beholds. Science from nature study onwards makes life safer and easier and reduces the chaos of experience to order by intelligent and practical control. Its function in the scheme of human affairs is to "make straight in the desert a highway for our God."

III. FUNCTION OF NATURE STUDY IN EDUCATION

THE starting-point in education is a response to environment on the part of the individual, as shown in attention and movement. A direct development of this primitive reaction is perception. Gradually perception is enriched and extended by ideas, and the course of the natural process of mental growth leads to observation. Just as movement enters into all perception, so is physical activity associated with observation. Thus learning and doing become inter-related processes. The habit of observation prepares a basis for intellectual development, and is necessary to the higher processes of thought. All the same, it must be borne in mind that observation in order to stimulate mental growth must have some definite purpose. The motive for observing natural phenomena is immutable and rooted in human life itself: it is to make them intelligible with a view to obtaining practical control over environment.

When the children are engaged in a process of observation in search of something which has previously excited their curiosity, each stage will have meaning and purpose, stimulating interest. The power of reasoning from facts will develop, and the whole process approaches scientific enquiry.

Tracing the growth of the course of scientific method no further than this early stage, it will readily be seen what contributions nature study makes to education.

By its constant reference to concrete realities and experienced fact it ensures that a wealth of ideas, and not only a wide vocabulary, is acquired. Such ideas constitute potent units of thought-life available for manipulation and elaboration. Thus nature study makes valuable contributions to mental equipment. Since it widens the range of organized experience, opening eyes and mind, stimulating the func-

tions of reasoning and inference, it will further general intelligence.

Apart from these considerations it is recognized that nature study establishes points of contact with the world of nature and sympathy with everything that is. The organization of facts is good, but finding their meaning is life itself: "With all thy getting, get understanding." Nature with her colour, her sounds, her varied movements, her incessant change, arrests attention; looking readily becomes "seeing," and a personal relationship is established between her and the learner for mutual benefit. The joyousness of observation and discovery, the discerning of beauty and fitness, and the health-giving open-air activity that nature study brings with it, make of it not only a brain-stretching pursuit and fundamental discipline, but contributes much to the culture of the senses and the development of the artistic emotions.

IV. CHARACTERISTICS OF CHILDREN RELATING TO NATURE STUDY

HUMAN instincts and tendencies are part of the legacy of the past of the race which forms the outfit of the present and of the future. They are universal possessions to which every human being, as such, has a claim. But this is not the only heritage into which the human child enters at birth. Its own particular parents, and its ancestors before them, bestow particular gifts unlike those of any other line of ancestry. Then there is the little child itself, apart from its bundle of inheritance—it shows congenital variations which make it unlike any other little boy or girl. Thus, if there were but these three factors in child-life, it is not to be wondered at that each little child is a new mystery.

There seems to be little doubt but that each human being passes in the course of its mental life along the same lines of intellectual achievement and progress as did the human race in the course of its growth from infancy. This statement is borne out by the discovery of many instances of parallelism that exist in the special mode of response which children and primitive races show to the call of nature. To mankind in its infancy as to the little child of to-day the world is *terra incognita*, it is of vital moment to both that they should understand in order to control. Instinctively they make experiences, they are impelled to do so, and their desire to know and to explain is preordained.

Children, like primitive people, are profoundly affected physically and mentally by marked change of seasons and by other natural events. There is a suggestion that hibernation and other trance-like forms of sleep marked primitive human life, and it is a common experience of mothers and nurses that the baby's moods vary with sunshine and clouds.

The little child's earliest mental response is characterized by attention and interest passing into ill-defined emotional states of wonder and dread on the one hand, and intellectual states of expectation and curiosity on the other. "Hush, all hush and see!" describes the attitude.

This wonder represents a state of mind which sways between fear and delight. Pleasure in shimmering colour, singing sound, striking form, and varied movement is for ever interwoven with the question, "Will it hurt me?" Uncertainty prevails until experience and information answers the question, and pain or pleasure takes possession of the mind. This question, "Will it hurt me?" is almost equivalent to "I fear lest it hurt me," and partakes, therefore, of the nature of emotion. As experience increases and confidence grows, the question more often gives place to another—viz., "What is it?"—which suggests an intellectual attitude of mind and implies a desire for intellectual control

over the situation. If only as much as the name is known of the new thing, the mind is more at ease, since it is able to cope with it, and form new relations with it in the region of thought.

This is the stage of making acquaintances and gaining experience. Everything within reach is grasped, including hot cinders. This learning by sense experience, accompanied by fluctuating feelings of pleasure and pain, is the earliest phase of nature study. It persists well beyond the days of infancy, as is seen when a little child is watched out of doors. The call of a bird will make him attend and probably imitate, but the next moment his attention is caught by a bright flower, which he will pick, may pull to pieces, and then throw away. He will see a butterfly, shout for joy and run after it, only to be stopped by the sight of some berries which he will pick and eat or not, according to the kind of training he has received. He will watch a spider making its web and a bee burrowing in a flower for pollen or nectar. All his observations are characterized by being based on involuntary attention to sound, bright colour, or movement, and by being superficial and of short duration. He is simply receiving new units into his circle of acquaintances. It should be noted that all such nature study is accompanied by free physical activity, running, jumping, and shouting for joy. Pulling, breaking, lifting, throwing, are all significant elements in the process of acquisition.

The prevalent question, "What is it ?", together with the destructiveness so characteristic of childhood, are all manifestations of our instinctive interest in environment to which we give the name of curiosity. It is older than man, and at the root of all intellectual activity, being of the utmost moment in the process of adaptation to conditions.

At a later period a tendency to account for, or at any rate to interpret, observed phenomena becomes evident. The significant question now is, "Why is it ?" These interpreta-

tions are an effort to bring new ideas into relation with old, and thus to reinforce the power of thinking. The interpretations have certain characteristic features, and investigation of these throws light upon some difficulties and problems of nature-study teaching.

1. There is a tendency in all human beings to regard whatever can be object of thought as a thing having independent objective existence. Thus when a little boy asked his mother, " What is the wind like when it does not blow ?" there is a clear indication of the searching of the mind for qualities with which to endow the thing " wind." This tendency is at the root of the process of personification which is so predominant in the minds of children and primitive people. We find that the forces of nature are conceived of as things usually alive, because they obviously bring about certain effects. Thus Jack Frost paints pictures on the window overnight, and Spring treads the earth softly, calling to the seeds underground to wake up. Even the very fear and awe which the unknown excites must be accounted for and explained. Sometimes good and pleasurable things come from the unknown; sometimes, on the other hand, evil, danger, and disaster. The primitive mind would contend that there must be things or beings that are friendly or hostile to man—perhaps they can be pleaded with, won by praise, propitiated by staunch support, by offerings and by sacrifice. Conditions of life in the present day prevent the child from offering burnt sacrifice to the powers of Nature, but the state of mind preparatory to it frequently occurs and may find expression " in play," to which reference will again be made.

2. The facts of visible nature are interpreted in terms of previous experience. But since in the case of little children this experience is limited and has strong personal colour, the interpretations arrived at are all humanistic in quality. The following will serve as examples. A potato had been left

sprouting in a biscuit tin, and the white shoots were straggling in a tangled mass in all directions. A child, seeing this, offered the explanation that the potato found himself alone in the dark (a most unpleasant situation) and that it had sent its shoots in all directions (being unable to move) to see if it could get out. Another child, being profoundly impressed by the condition of a bulldog's legs, exclaimed: "Look, they have let the poor doggie walk too soon!" Most of us who have intercourse with children could bring forward countless instances of this same form of reasoning, whereby man is read into the ways of beasts and plants, and even of inanimate objects.

From these remarks it follows that teachers of nature study take note of the facts that the attitude of little children towards the phenomena of nature has strong emotional elements, that this response to the external world is marked by curiosity, inquisitiveness, and destructiveness, and that the ideas which characterize the child's intercourse with nature are brought into correlation with one another and with pre-existing ideas, so that the phenomena acquire meaning. The finding of meaning is dominated by the universal tendency to personify natural phenomena and to account for them in terms of experience.

All the earliest phases of nature study teaching concern themselves with this aspect of intercourse with nature—viz., to wonder, to inquire, to make acquaintances, and to find meaning. But soon further signs of growth and change are noticeable. General curiosity has led to many discoveries and to a considerable range of knowledge, and the child becomes more self-reliant with ever-increasing physical strength and prowess. More and more daring does he become. Investigation and pulling to pieces "to see the wheels go round" are extended into exploration and adventure. The spirit of adventure is now fully awake. To see what happens if . . . is the motive of many actions

that strike terror to the heart of anxious parents. All these activities gradually extend to discoveries, contrivances, inventions, which materially lighten the burden of life. It is important to notice that this end more or less fortuitously attained, or at least purely instinctively sought, becomes the conscious motive for fresh enterprise. The desire for knowledge and intellectual control is thus strengthened and specialized by the motive of purpose and utility. The practical value of discoveries is a matter of special interest. This phase is characterized throughout by a superabundance of energy, by great motor activity, and by the practical value of all intellectual achievement.

It was at this stage in the days of old that defence against the attacks of wild beasts assumed an aggressive character and hunting and warfare became a new passion. Times have changed, and there is little opportunity for the chase in an ordinary child's life, but rudimentary fragments of this response to wild nature's ways are nevertheless still in evidence. Before a city boy has time to think of purpose, ways, and means, off goes his cap at the sight of a butterfly flitting across the path in the park, and most elemental movements of arms and legs in the direction of the fugitive suggest the burning desire to capture the wild beast. The impulse to throw stones at every cat, that is not his own, and to pursue it with a war-cry is a dream of the past on the part of the "bad" little boy. The stalking of the first violets under the hedge and springing on them with a yell bears a distinct resemblance to the ways of the past. Increasing control of environment presents opportunity for the instinct for acquisition to assert itself even in the material plane of existence. The laying up of treasures, the accumulation of wealth is the result—be these food stores, tools, materials of æsthetic worth, or, in the case of children, shells, stones, seaweeds, birds' eggs, or, failing all, postage stamps. Animals are captured for pleasure or for use.

Of this our domestic animals bear evidence, and the white mice, rabbits, canaries, silkworms of the present-day school child corroborate it.

Besides living in the world of sense and practical realities, much of the child's activities take place in the regions of the mind and find outward expression in play and story. Thus, when the call of the past is most insistent and instincts impel to particular lines of conduct, the conditions of life that surround him may present no opportunity for adventure or accumulating wealth or curing the sick, and he will seek these experiences in imagination. In his play he experiences all the exciting adventures of a successful hunting expedition and comes home with a sense of high achievement showing his trophies to admiring companions. To the uninitiated he appeared to have gone to the far end of the back garden, to have wildly gesticulated, to have picked up some stones and leaves and to have presented them to some stakes in the fence. It would be easy to give many instances of make-believe, but the process is too well known to need detailed description. In his play the child shows a craving for increased and varied experiences and for experiments in living which his daily life denies him.

It is obvious that make-believe in children, and the form of untruthfulness which we call romancing, are not separated by hard-and-fast lines. Adults take pleasure in the former and regard the latter with concern, if not actual dismay. Teachers of nature study very frequently encounter highly coloured romance which is delivered breathlessly and with eyes flaming with excitement. Some examples may make the situation clear. A teacher gave some lessons on the birds of the neighbourhood, pointing out to the children the signs by which they might know them and their habits. What was her consternation when a child reported, with signs of transporting joy, that she had seen fourteen woodpeckers on her way to school along a road which had more suburban

than rural characters. Another day an exciting story of parent birds feeding their young was told at a time of the year when such a phenomenon could not be witnessed. The eager response to the request that the children should try and find a specimen of some special plant or animal often consists in the remark: "We've got hundreds in our field," although this could not possibly be the case. A vivid description was given to a little boy of the manner in which a dragon-fly dealt with a butterfly. A whole year later the boy told the story, as his own experience, repeating details, even of phraseology.

In each one of these cases, indeed generally, the honour and integrity of the children can be vouched for, and the conception of original sin does not account for this peculiar behaviour. Grown-up people may charitably put the stories down to a vivid and uncontrolled imagination, but it seems more likely that the children have not yet learnt the distinction between the world of objective realities and the region of thinking and dreaming, and under the spell of burning desire they cannot keep free the memory of experienced fact from the vision of what might have been. In the proportion that the children's abundant energies are engaged in the affairs of practical life, and in ever-new adaptations to the real world, in that proportion will they learn distinctions between actual experience and fancy and will control their ideas instead of being carried away by them.

SECTION II

THE TEACHING OF NATURE STUDY

THE foregoing outline sketch of the meaning of nature study, of its scientific character, and of the characteristics of childhood which should determine its course and form, enables us to come to some conclusions as regards the selection of suitable subject matter and the manner of teaching it.

The main object of a course of instruction in nature study is to educate the children's innate curiosity regarding their natural environment and to foster their love of nature.

This aim must be pursued with singleness of purpose. The significance of the study of nature as a factor in human achievement will only be realized in a disinterested pursuit of the subject. If the science of life is taught for the sake of its value as a mental discipline, or for the acquisition of scientific principles, or for the right governance of the practical affairs of life, it cannot become a potent influence in the life of the children.

In recent years a fresh interest has been taken in hygiene, since the complexities of life in the present day, especially in cities, make it imperative that there should be widely diffused knowledge of the principles of healthy living, both for the individual and the community. It is realized that biological science provides opportunity for the practical study of the various aspects of life, and therefore forms a rational foundation for hygiene. This is obviously sound, but there is a grave danger, if biology is taught merely as ancillary to hygiene, of laying undue stress upon the facts that bear some relation to human well-being. This results in a distorted view of life and a narrow conception of hygiene.

But while rejecting the heresy of estimating the educational value of nature study by its relation to personal and social hygiene, we may admit, and indeed emphasize, its

practical value in the life of the pupils. It is not inconsistent with disinterestedness and freedom on the part of the pupils that the knowledge acquired makes for foresight and control. It should be possible to work out a course of elementary biology, which, if pursued for its own sake, will provide the concrete material, practical experience, and the wide outlook for effective hygiene. Such a course must, above all, appreciate the child's point of view. Its keynote must be experience in the light of which biological truth can be realized, and theory must not be in advance of such experience.

General Principles of Instruction.—Since nature study represents the response of the child in an unexplored but *a priori* interesting environment, the latter should, as far as possible, be shown as a complete whole. It is therefore incompatible with a true conception of nature study that schemes of work demand a series of lessons on the buttercup family, winged fruits, insects, or rodents. Clearly in such a case analysis and generalization have already acted upon experience, and children receive in systematized form what it was their right to discover. Similarly, topics for a year's study are sometimes grouped under such headings as animal life, plant life, or physical conditions; this again implies a premature breaking up of natural relationships and a rearrangement of them on a logical plan which only a trained scientist can appreciate.

There are strong arguments in favour of a seasonal course of study, apart from obvious convenience and general harmony. Seasonal study of nature being racially primitive will the more readily stimulate the children's spontaneity. Further, since we ourselves are but links in the chain of living organisms, we are strongly affected by the rhythms of the year, and live in tune with all that appears in "due season." The recognition of such subtle relationships will give a living touch to our teaching.

A point frequently discussed must be raised at this stage. With the majority of teachers the word "nature study"

connotes the study of animal and plant life in a scheme of science. Obviously this is not in keeping with the actual, literal meaning of the word, nor yet with the conception of nature study as indicated in the account given in these pages and generally accepted in theory. By the terms of the whole theoretical argument, the experience of children must be of nature as a whole, unanalyzed and unclassified, and the physical aspects of air and sun, water and earth cannot be ignored without distorting the pupil's vision.

The discrepancy between theory and practice, more apparent than real, has probably arisen from the recognition that the aspects of nature, which first arrest the children's attention and hold their interest, are associated with animal and plant life. Doubtless, there is between the child and living things a kinship of which he is dimly aware, and which renders the ways of his "kindred of the wild" more interesting and more intelligible to him than the more remote physical elements. It is, therefore, not only permissible, but necessary that living things should be the centre of interest in the earlier phases of science teaching. But life is a web of infinite complexity; the life of plants and animals cannot be rightly understood apart from the relationship of each to the other, and both to the physical environment. When that stage is reached at which an understanding of the phenomena of life is sought, some of the more potent factors in the physical environment of plants and animals must be investigated.

Although nature is as yet a complex whole, the attention of the little stranger in the land will pass voluntarily or involuntarily from one phenomenon to another. Since, then, there is normally a sequence of varied experience, schemes of work should reflect this fact, and may consist of series of lesson units, each of which is intended to extend over one or more lesson periods. Again, modelling our programme for work in school on "real life," we take pains

that the lesson units are organically connected, having some definite relation to one another. The connection between our lessons will, however, be psychological rather than logical. All such facts as might reasonably constitute a child's experience in time or place will form a series of lesson topics upon which attention may be focussed. Thus an actual or imaginary walk along a lane in spring may become the foundation of a lesson course. Puddles left by April showers, primroses, unfolding buds, the humble-bee, the earthworm, and the woodmouse might form a suitable course of studies, all the topics being linked together in thought as they were presented in experience. Similarly, the preparation for winter made by living things would form a suitable related series.

Nature study should be simple, direct, and concrete. There must, therefore, be contact between the child and the objective reality, and first-hand acquaintance with things and processes in nature. This, where city schools are concerned, constitutes one of the greatest impediments to the successful treatment of this early stage in science teaching. To provide sufficient material characteristic of one place or one season for a series of lessons is a matter of considerable difficulty. The remark, often made, that there must be actual material for study in our nature lessons, or, if this is not possible, a very good picture of the object must be provided, is at once a temptation and a denial of the fundamental principles of nature teaching. When the burden of the day is heavy upon the general class teacher and every subject makes its claims on time and energy, a "very good" picture which remains quite fresh in the cupboard from year to year will certainly be a welcome refuge for the destitute. That by this act, however pardonable on other grounds, they sell their souls as nature study teachers is obvious, for they withhold from the children first-hand experience and provide them with material that has already passed, at least once,

through the alembic of a human mind. It must not be supposed, however, that specimens need be provided for each period of study, as long as the lesson unit, which may consist of several such periods, centres round some direct experience.

The difficulty of the supply of adequate material for study, especially in the poorer city schools, is so great, that it cannot be ignored or passed over without some suggestion towards a solution.

The problem would be very much reduced in complexity, if not entirely solved, if all the nature study in the school were in the hands of a specialist. Such a person would presumably be a naturalist to whom collecting from the treasuries of nature is a personal and vital need. Temperaments and interests among teachers vary so widely that to expect any members of the staff of an elementary school or of the junior department of a secondary school to go out into the country and bring home creatures and flowers for the pupils, is both unreasonable and unprofitable. It is only one to whom the process is a delight and recreation who would not find this duty a burden. It cannot be too strongly urged that this work, so special in its outlook and in its practical needs, should be in charge of a naturalist born and trained. It is a sign of better things coming that specialization has begun in elementary schools also, and many of the ordinary class teachers are now permitted to teach subjects for which they may have special aptitude in classes other than their own in exchange for lessons less congenial to them.

A born naturalist with trained vision will find material for study, exemplifying many of the most important natural phenomena, in the most unlikely places. If it is possible to find seedlings of fifteen different kinds of trees and shrubs between the flagstones, against garden walls, and in heaps of mould and street dust accumulated by eddies of wind in sheltered corners of a road in a London suburb, and if it is

possible to obtain material for a whole course of nature lessons on a suburban station platform, then one realizes that the case for nature study in towns is by no means hopeless. Although roaming in wide fields of nature and direct experience with varying phases and facts is beyond compare and conducive to breadth of outlook and of judgment, yet it is also true that the "flower in the crannied wall" has a story to tell of sunshine and rainstorm, of growth and change, of struggle, failure, and achievement, and that may well set one furiously to think. Thus, while fully recognizing that the finest part of the "little flower's" secret will only be perceived by those attuned to the manifestations of nature free and open, yet the facts and processes of nature that have permeated our cities are sufficiently significant to excite wonder and provide mind-stretching exercises.

Progress in nature study does not primarily depend on wealth of material. A skilful use of opportunities, inspiration, and unfeigned enthusiasm are necessary. A scientific method of procedure determined alike by the teachers' direction and the pupils' work must also characterize the study.

It cannot be too often repeated that nature study must be direct and concrete, that the pupils' curiosity in living things should be stimulated and trained, and the foundation of science prepared. The function of practical lessons must be to provide opportunity for the discovery and determination of actual facts of importance and interest to the children; such facts may or may not be recorded in drawing, writing, or speech. In the case of older pupils a subsequent period may be given to discussion of the comparative importance of the facts as data for inference and interpretation. In such cases theoretical work has been attempted. It will, however, generally happen with young children that practical work and theory cannot be thus definitely separated.

The need of making nature study graduated in difficulty and progressive in its course is often overlooked. It even happens in some schools that whenever a supply of specimens is obtained these are passed on from class to class throughout the school and duly described. As the range of available specimens in city schools is limited, the work lacks in variety of experience. Thus, fruit and seed dispersal, the growth of the bean, method of pollination in flowers, confront the child in due season throughout the course of his nature study with the inevitability of fate. In other schools a programme is made for the different classes, and a fresh set of objects of nature is studied in the course of each class. This ensures wide and varied experience, but it implies the fallacy that the life of one organism is more difficult to study than the life of another. It is true that the circle of acquaintances is widened, but there is not necessarily any change in intellectual reaction, and there is hence no scientific training.

Although both the methods of procedure may miss the most essential elements in nature study teaching, they show effort in the right direction, and any inefficiency in teaching may be referred to a want of imagination and sense of humour on the one hand, and ignorance of the vital needs of science on the other.

Thus, in the first case, it is true that man is never weary of witnessing significant scenes in the pageant of the season, but it is forgotten that the spectators of the pageant, changing from year to year, behold the scenes in different frames of mind as the years pass and react to them differently. It is necessary, therefore, to present the material for study in such a way that it reveals fresh meaning each year in accordance with the interest of the pupils. Fruit and seed dispersal may fitly be considered in the autumn during more than one school year, but both the manner of presentation and the method of approach as well as the response on the part of the class should change from year to year.

In the same way, the second type of syllabus should, in addition to widening experience, provide for the changing attitude of the pupils and the increase of mental effort.

In preparing the syllabus, therefore, it is well to bear in mind that the pupils normally pass through definite stages in the development of the scientific interest and that each stage should receive attention. The stages in mental development that concern nature study teachers directly have been outlined in the section dealing with the characteristics of children as regards their attitude to the realm of nature, and the subject matter for a course of instruction is prepared in accordance with those phases of interest.

SCHEME OF WORK

Stage I

This stage applies to children before the age of nine or ten years. It is characterized by great curiosity, as regards the outside world, especially as regards other living beings, whose behaviour rather than appearance excites interest. Attention is rarely sustained unless it is accompanied by play, especially such play as will involve bodily activity. To make a snail crawl up a stick, to give a rabbit something to eat, to make a fairy doll out of a poppy, are some of the characteristic reactions of the young scientist. The work in the lessons at this stage should be quite informal and anything like systematic questioning on the part of the teacher should be avoided. The spontaneous comments, conversations, and questions, the expression of fear, wonder, and joy should all be as unchecked as the orderly life of the community will allow. If anything like direction and definiteness is thought

advisable, drawing and colouring of pictures will provide suitable opportunity.

The seasonal aspect of the study will be throughout emphasized by drawing attention to and discussing the weather, and by the presentation of typical subjects. Large heads of sunflowers, snapdragons, and nasturtiums will provide an experience of flaming colour among flowers, and leaves of virginia creeper, chestnut, and beech will emphasize it yet more. Dandelion clocks, bunches of old-man's-beard and thistlehead will give opportunity for playing with soft fluffy material and set some seeds a-sailing. The wind will do this more effectively, and the voyages through the air take the seeds to far-away places. To tell that this process is of service to the plant would be one of the instances when an explanation is given far in advance of the children's range of experience, which must be strictly avoided. All the fruits of the greengrocers' shops, together with hips, haws, and berries from the hedgerows, will give the impression that autumn is the time of fruiting. Fruits are good to eat and serve as food, not for us only, but also for thrushes, blackbirds, wasps, beetles, ants, and slugs. The possession of nuts with their hard shells will lead to thinking and experimenting as to ways and means of opening them without destroying the kernel. How do the animals manage? Bulbs, parsnips, carrots, are parts of plants which have died down. Some serve us as food. Keep some in the school garden or a flower pot and see what becomes of them when they are not eaten. The Christmas tree with its needles, the wonderful stories that are told about it, the making of ornaments for its festive decorations, holly and mistletoe, beloved of all, will keep thoughts and hands well employed when the frost-bound earth seems lifeless. When there is a smell of spring in the air, it is time to think of the good things to come and look up the seeds in their packets and in due course sow some of them in pots and boxes. The shoots of bulbs are appear-

ing. Turnip tops and carrot tops show fresh green—the turnips and carrots themselves growing limp, a most significant fact. Lambs' tails and willow pussies will decorate the class-room long before Palm Sunday claims them for its ritual. Twigs with glistening, sticky horse-chestnut buds raise the vexed question every year, " Shall I touch ? Shall I not touch ?" Then frog spawn is laid and tadpoles are born, an ever-new wonder, and no one is tired of watching them. In the summer time late primroses, cowslips, bluebells, buttercups, and daisies occupy attention. An aquarium contains a pair of newts and some sticklebacks, and in a box with tufts of grass and moss is the temporary house of a toad and a frog. Thus the march of time sets free new wonders at each step.

The keeping of frogs and toads in captivity raises the whole question of school pets, a subject of warm discussion among teachers of young children. Clearly much is to be said for the practice from the educational point of view. To care for little creatures in our charge and make efforts for their welfare is service which honours the servant; instinctive, thoughtless cruelty is displaced by a new and stronger interest. Continued observation of growth and habits leads to actual knowledge based on experienced fact, which no amount of information can supply. Cruelty can be reduced to a minimum by providing adequate accommodation and regular attention to the little creatures' ways. Also animals should be chosen whose life is not marked by outstanding activity and enterprise, and who easily adapt themselves to domestic life. Moreover, animals like rabbits, guinea-pigs, and doves that are actually born in captivity will take little harm in their capacity as school pets. Nevertheless, the keeping of pets involves great responsibilities which little children do not always realize. Also in many schools overcrowding of the classroom and difficulty in ventilation, in any case, produce unhygienic conditions, so that the keeping

of pets, which means additional organic impurities in the air, becomes distinctly undesirable.

If there is some suitable passage, landing, courtyard, or garden, the practice of keeping pets has clearly a preponderance of desirable elements, but only in large and well-aired classrooms where the children may move about freely can animals in cages be suitably accommodated. (See Keeping Animals in School, p. 45.)

Feeding the animals is always an interesting occupation, and wherever possible nature lessons should coincide with their meal times. In the same way, preparing homes for animals kept temporarily in captivity is an extremely useful occupation and quite possible with small classes or with groups of children selected from large classes.

Wherever the provision of suitable material presents no great difficulty, young children should be allowed to play with their nature treasures. Such play, like the rolling of chestnuts and acorns, the plaiting of rushes and grasses, the stringing of rose-hips or daisy-heads into a chain, the making of garlands of leaves pinned together with grass stalks, will certainly lead to discoveries as regards number, form, colour, texture, which systematic questions on the part of the teacher could never bring about. Throughout, the lessons should be much more in the nature of play and should involve incidental discovery rather than a process of deliberate investigation. Fanciful interpretations on the part of the children should at all times be accepted, but the teachers should preserve an element of sincerity and avoid explanations which are not true to fact—better still, avoid explanations altogether, except in answer to a direct question.

Suggestions for Stage I. Syllabus

1. Examination of the different kinds of corn. Learning to identify ears of corn and grain. What becomes of the ripe corn ? Harvest and harvest festivals. Mice and birds which share the harvest. Ears of corn and grain left on the ground—what becomes of them ? Place some ears and grains on a flower-pot saucer filled with earth and keep moist.

2. Examine without dissection and paint some of the large bright autumn flowers—*e.g.*, sunflower, dahlia, nasturtium, poppy, and bean blossom. Notice undeveloped and ripening seeds and seed vessels and find out from which part of the flower they come.

3. Look at pictures and museum specimens of dormice, squirrels, and hedgehogs, unless living animals can be seen. This is their season of plenty. Squirrels and mice feast on nuts and other fruit, hedgehogs on mice and insects in cornfield and hedgerows. Read descriptions of the ways and habits of these little animals (*e.g.*, "Wee Tim'rous Beasties," by Douglas English).

4. Find leaves which show autumn tints. Paint as many different leaves as you can. It is useful to provide the children with envelopes and help them to collect fragments of coloured wool, cloth, silk, bast, paper. It can be called colour collection Children will exchange a little piece of purple for a piece of green. They will magnanimously make a present of a fragment of red to someone to whom they wish to show favour. In the course of time each child will have an assortment of colours the collection of which implied unconscious effort in colour discrimination. If the beauty of a virginia creeper leaf surpasses our power of verbal description, we can find a fragment in our colour collection to match each shade of colour in the leaf.

5. Bulbs are provided for the classroom, and the children

assist in planting them. Before the bulbs disappear in the ground pictures are made of them and the date is written underneath. These pictures are kept for later comparison. It would be interesting to make another picture showing what each child thinks as to the appearance of "flowering shoot" which will grow from the bulb. These pictures are prophecies—will they come true?

6. Nature lessons on Christmas tree, holly, mistletoe, involving examination of drawing of actual specimens. Folk stories and legends about these plants.

7. Sparrows, pigeons, gulls, rooks. Observations made on these birds in the open and the signs by which they are recognized carefully noted. How do they find their food in the winter? Inspection and painting of birds' feathers obtained from the poulterer. Collect bird cigarette pictures, post-cards, cuttings from magazines and newspapers, and make a bird album.

8. Seeds have always been delightful things to play with. They can be laid on a table to form patterns, or if they are soaked overnight they can be made into a necklace with needle and thread. The necklace can have a definite pattern, if care be taken to count the number of each kind of seed taken and repeating the arrangement in a definite way. Seeds of different kinds of peas and beans, also sunflower, marrow, and maize, are pleasing in shape and colour. Some big seeds, also acorns, Spanish chestnuts, and beech nuts (where the seed cannot be separated from the fruit wall) can be made into toys representing household furniture, utensils, comical animals, etc., but clever fingers are needed for this. Seeds, at least the larger kinds, can be modelled and make pretty brushwork sketches; they always make one think of sowing and planting. Small seeds, such as mustard and cress, might be sown in a small wooden box and kept in a window, and some larger seeds, such as peas and beans, planted in pots, and yet others with hard skins, such as

acorns and chestnuts, might be grown over water. In the latter case, seeds should be looked for that have started to sprout or should be induced to sprout in a tin with some wet moss or blotting paper, otherwise they take too long to grow, as the air over the water does not contain sufficient moisture for growth.

In the course of play and painting, and during the process of planting, the names of a few kinds of seeds have been learnt incidentally; now while we are waiting for things to happen we may make the acquaintance of yet other kinds of seeds, learn the signs by which we shall always know them, and learn the name which belongs to them. Seeds of various kinds of beans and peas, pumpkins (from parrot food), sunflower, maize, barley, oats, wheat, mustard, cress, linseed, onion, will extend the circle of acquaintances, and will prevent the prevalent notion that the seed is always a bean.

9. The study of such inconspicuous objects as the buds and markings of twigs in winter is not attractive to young children, but class or form teachers should not fail to have a few branches of several different kinds of trees in the class-room in jars of water. In the warmth the buds begin to grow early, and when some glisten, like those of poplar and chestnut, and others show little pale green spaces between the brown scales, the children take pleasure in the change and appreciate the beauty of the unfolding. Among the twigs some specimens of hazel will be displayed, and as the catkins open, they can be shaken as if the wind blew through them and clouds of yellow pollen will fly like dust in the air. We enjoy seeing this. Likewise the silver willow-pussies or "palm" are obtainable; the children can watch some changing to yellow, while others change from silver to grey-green.

10. The study of spring flowers. There is no surer way of making nature study joyous in springtime than by letting

the children come into contact with spring flowers. In the cities snowdrops, tulips, narcissi, and violets are brought to the market very early. Some of these treasures have come from countries with more genial climates, and others have been grown in the shelter and comfortable warmth of greenhouses. Since some of these flowers appear in the florists' shops before Christmas, and since we know that they have not grown out of doors, we do not look upon them as the acclaimed heralds of spring, but when a child brings a few snowdrops from his own garden, or announces that the crocuses are actually in flower, it is then that our whole being responds to the call of springtime. The beauty of spring flowers is so striking and so simple that it appeals to all the children, and they respond with whole-hearted affection. They handle the flowers gently and take pleasure in caring for them, so that they may keep fresh as long as possible.

It stands to reason that anything like systematic description is out of the question with young children. A conversation about the flowers, such as would take place naturally between the child and the mother or nurse on a subject of common interest, is all that should take place. Such a conversation would have reference to the name of the flower; the colours, how far such colours were like or unlike the colours of other objects in the room; the scent and of what other scented things it reminds one; the flower leaves or petals and the number of these in each flower in the room; discovery of other pretty little structures in the centre of the petals. The grouping of the flowers in a vase, and the placing of the vase in a suitable position, are matters of importance. If some interesting folklore or legend is associated with the particular flower, or if it is spoken of in good poetry in a manner intelligible to the children, no more suitable moment for acquainting the children with literature on the subject could be found. The senseless practice which

prevailed until recently of appending a story to every nature lesson, however pointless, in a false correlation, is fortunately becoming rare. The pleasure that the children take in seeing and handling flowers is exactly the right frame of mind for making " lovely " pictures of them. How far the artistic or the scientific tendencies of the children come into operation depends on their individuality, and as no formal science work has as yet begun, it is not necessary to insist on a careful record of observation.

11. Frog spawn is a much-coveted possession in a classroom. It awakens great expectations. Like the seeds it makes constant demands on watchfulness. Within a few days it changes visibly, and then there is no end to the possible discoveries. Little lively tadpoles appeal to the affections of the children. The tadpoles require care and attention; the class is responsible for their welfare. An aquarium must be prepared for them, and this must be an ornament for the classroom (see " The School Aquarium," p. 69).

12. Lessons on frogs, toads, newts, and sticklebacks. Such lessons consist largely of observations on general appearance and movements and of comparison. Frogs, toads, and newts are capable of being drawn by the children. It is sometimes useful to give the children hectographed outline pictures of frogs and newts for them to paint with the correct colours.

Stage II

The pupils make the acquaintance of many living things as the pageant of the seasons brings these to their notice. They enter into a happy and sympathetic relationship with plants and animals as a natural reaction to interesting and beautiful things, events, and processes, and they arrive at an understanding of their ways.

It is essential that the work at this stage should provide wide experience, and that the children should have "free play for variation" and individual reaction, emotional and intellectual. There must be room for unconventional exploration and intellectual adventure. No attempt must be made to ensure premature grasp of principle.

The work consists in the study of living things from the point of view of the interested spectator of the pageant of the seasons. Great events are selected for more detailed study, such as fall of leaves, scattering of seed, migration of birds, sowing and growing of seeds, pond life, flowers, insects.

Ornamental nature calendars and weather charts will record seasonal change. The construction of portfolios, the making of leaf prints and spore prints, the making of breeding cases and vivaria, will give scope for creative and constructional work, which is a natural expression of the children's interest and pleasure in the work.

This stage is characteristic of children of ten and eleven years of age, and is marked by excessive motor energy. It is the age at which great prowess is displayed in the throwing of stones either at particular objects or to ever greater distances. Throwing of stones over and into the water is an obsession which, starting at this age, never loses hold of man. It is the age when constructing a system of drainage, or a wall or fence, is of greater importance even than sowing and planting in the garden; when preparing and constructing housing accommodation for caterpillars or silkworms is so engrossing an occupation that the creatures meanwhile wander far abroad for all the architect cares. "Whatsoever thy hand findeth to do, do it with all thy might," is the decree spoken to the children.

If this is the natural response of the children consequent upon their intercourse with nature, it will be the business of

the nature lessons in schools to provide not only practical but much constructional work. If a topic of interest presents itself, everything that wants doing and making in connection with it should be done and made. The objection that this would be handwork and not nature study will be met by the reply that reactions to the claims of environment are not in real life grouped into categories kept apart by reason and logic, and just as the gardener does not fetch other craftsmen to drain his plot or whittle his sticks, but is a man of many parts, so the children's business out of doors is manifold. Likewise, therefore, must our work in the nature lesson show varied practical activity, if it is to preserve an element of spontaneity and conform to the attitude of mind of the children at that age.

Under the ordinary conditions of a classroom it is not easy to organize such work, and some teachers may even find it to be out of the question. As this work has been known to proceed satisfactorily, it cannot be considered impossible. Again, it must be emphasized that the difficulties can be immensely reduced if the work is in the hands of a specialist, and if group teaching prevails in the class.

Every school, elementary and secondary alike, should be provided with a practical room where all forms of nature study, but especially nature study combined with manual work, can be carried on without unfair strain and effort on the part of the teacher, and without placing difficulties in the way of the work of little children, which adult craftsmen would never tolerate. Some illustrative specimens of courses of work of this kind may be briefly indicated to make the meaning of the above argument more definite.

(*a*) In the autumn term a collection of fruit may be made, without attempting any classification based on structure; thus fruits of trees, fruits of garden plants, fruits of wild flowers, might be collected and preserved. Obviously, this

will make the children feel the need of a suitable box with divisions, and such a box must be constructed.

(*b*) We recognize trees and other plants by their leaves, which are very varied in shape. The latter are easily obtainable in the autumn. Let the children learn to press them, mount them on sheets of paper on which short descriptive notes may be written. A portfolio for these sheets must be made.

(*c*) In the spring term preparation for sowing must be made. Small wooden boxes may be constructed or existing ones mended and strengthened. These are to be filled with soil, carefully prepared, and seed is sown. If climbing plants have been sown, trellis work must be provided, and throughout the plants must be judiciously cared for and records of observations must be kept.

(*d*) An aquarium may be prepared from a large jam-pot embodying all the principles that govern successful pond life. This will be stocked with things which will make further claims on the resources and time of the owner.

Although practical work is a distinctive feature of nature study at this stage, it does not mean that purely intellectual pursuits have no place. It will be found that whereas simple facts of appearance and of behaviour satisfy the children who are at the making acquaintance stage, and whose intellectual activity consists in perceiving fresh things and distinguishing them from other objects and giving them a name, interest in relationships now increases rapidly. At the earlier stage note was taken of the fact that the frog was brownish-green and had darker spots; it will now be discovered that such colour matches the colour of the bank and the moss, making it quite difficult for us to see the little creature if it does not move. In this way the children note relationship and discern biological significance in individual and particular instances.

This attitude of mind corresponds nearly to that of the

teacher, with the difference that tendency to generalization is a mark of adult thinking. The danger is, consequently, that children are not only forced to perceive such relationships by suggestive questioning, but it is presented to them in the form of a generalization of which the case under consideration is a particular illustration. Again, the child is only beginning to discern meaning in relationships; thus he notes the colour of the frog and of the surroundings, perceives similarity and realizes that because the frog is coloured in this way (lucky for it!) it cannot easily be seen; yet the teacher's adult mind, ever seeking for cause and effect, presents the two correlative facts of harmony in coloration and consequent safety as cause and effect. "Why is the frog coloured just so?" is a general question, and the child cannot choose but say, "So that it cannot easily be seen." This answer will come all the more readily if he has been taught the same general assumption as regards protective colouring on some previous occasion. Ever afterwards a particular mental button need only be pressed, by a particular form of question, and without corresponding knowledge of fact or exercise of reasoning, the same answer will be emitted. Not only is this far removed from scientific procedure, soothing though it may be to the restless enquiring mind, but it is a type of argument which must further be condemned as a conclusion based on quite insufficient premises, and one which is not borne out by experienced fact in nine cases out of ten. Only trained naturalists realize that the ways of nature are not as simple and straightforward and easy to discern as some would have them, and many a pair of facts that appear to have some causal connection are merely concomitant events that, occurring together, have some particular result.

Obviously, as a general rule, we would encourage the children to look for meaning, but by worrying them with the question "Why?" we not only distract the children's atten-

tion from their particular line of thought, but we constrain them to explain facts in the way we set conundrums, and to which the child's only reply can be, "I give it up." Unless the children ask the question "Why?" and thereby show that they would like to know the answer, they have no special motive for reasoning, and will therefore not exert themselves whole-heartedly.

Reference at this stage to the seasonal changes and the weather will constantly be made, and observations may well be recorded in the form of wind charts, weather records, and nature calendars.

Suggestions for Stage II. Syllabus

1. Fruit and seed formation and dispersal. Examination of autumn flowers at different stages of change, so that the development of the ovary and the formation of the fruit may be traced. Care must be taken to avoid presenting the subject of fruit and seed dispersal in a series of generalizations, such as, "Fruits and seeds dispersed by the wind have winged or hairy appendages, and those dispersed by animals are juicy and brightly coloured." Such formulæ are easily learnt by heart and repeated mechanically when the proper season for their repetition arrives. Data relating to the general principle of seed dispersal must be collected by the pupils themselves, so that they may experience a fundamental element in scientific work. (See "Living Creatures," chapter xxv.) Written and verbal reports of incidents relevant to the subject in hand, with or without illustrations, will occupy the class at the outset. In the course of time, classifications of fruits and seeds according to the manner of dispersal can be attempted. There is probably no better way of providing a clear survey of the subject studied than the construction of a fruit and

seed dispersal chart. This might consist of a large sheet of paper divided into sections according to the number of agents or conditions of dispersal. Each column may be headed by an imaginary or symbolic picture suggesting the special mode of dispersal. In the space below each picture, drawings of fruits and seeds scattered in this manner may be arranged.

2. Practical study of leaves and trees. In the previous year the pupils, attracted by the bright colours of autumn leaves, gave that aspect of tree leaves special attention. The desire to collect, possess, and have some practical control over the fallen leaves of trees is a natural reaction to their wealth and variety. The teacher might press and mount a large representative number of leaves in preparation for this work. Each leaf should be mounted and clearly named. The whole collection is displayed in different parts of the class-room. The children are encouraged to identify their own leaves, in their own way, as naturalists identify the specimens at a museum. The leaves may be pressed and mounted and the sheets kept by each pupil in some portfolio or envelope made and decorated in a practical lesson.

Further practical work, which provides "beauty feasts" as well as increased experience and knowledge, is the making of skeleton leaves, carbon prints, and photographic prints. Skeleton leaves may be formed naturally, some time after the leaves have fallen, but they are rarely perfect. Leaves with strong veins—*e.g.*, oak—are soaked for a week or more in a solution of caustic soda and then washed, pressed, and dried. They are next placed upon a pad of cloth or blotting-paper and beaten with a clothes brush, when the tissue between the veins will break away, leaving the network of veins.

The carbon prints are prepared by means of candle-soot mixed with a little oil, or by means of finely powdered char-coal, or Paris conté. The underside of the leaf is blackened,

laid upon white paper, and evenly rubbed. A beautiful print of the leaf surface is the result.

Photographic prints may be produced by means of sensitized printing paper. The leaf is laid upon it and kept in place by means of a printing frame. A much simpler and cheaper process for class production is brought about by the use of engineer's "blue paper." Upon this the leaves are laid, held in place by a piece of glass, and exposed to the light. No special solution is required for fixing the prints. They are simply left in fresh water for some time and then dried.

3. Lessons on wasps, spiders, and snails and slugs should take place some time in the autumn term, as it will be easy to find an abundance of suitable material.

4. Seeds and seedlings. It is important that the study of some particular subject should take the form of an unbroken argument, and in the case of subjects involving change, observation should be continuous and prolonged.

Seeds are presented to the pupils of as many different kinds as possible, and by a process of comparing and contrasting they learn to recognize the different varieties. Seeds which are easily obtainable are bean, pumpkin, pea, sunflower, maize, barley, oats, wheat, mustard, cress, linseed, onion. Dissection may be attempted with older pupils, and drawing and colouring should accompany the study. Will the seeds grow ?

Seeds are planted according to tradition and custom—viz., in pots of soil—and supplied with water, and they are put on the window-sill. The number of seeds in each pot should be counted and records kept of their subsequent history. Special attention should be paid to the behaviour of the seed-leaves (cotyledons) and the seed coat, noting whether they are lifted above ground or not. Why are some lifted above the surface ? The question cannot be satisfactorily answered because we cannot see what goes on

underground. Could we plant them in anything else but soil, so that we can see them ?

Plant seeds in lamp chimneys, test-tubes, or tumblers. First line the vessel with blotting-paper and loosely fill up the centre with moss or cocoanut fibre. Push seeds between the paper and the glass, and their whole development is under observation. Grow many seeds and make record charts of the different stages of the germination of each. If soil is not necessary, what about light, warmth, water, air ?

Experiments must now be made to ascertain the effect of water, air, warmth, light, in order to determine whether they are essential to germination or merely incidentally present. It is easily argued that the seeds kept in the corn chandlers' shops do not grow, but as soon as they are kept moist they germinate; water is therefore necessary. In what way ? Need it be merely present or is it used up ? Soaking a bean in water, we see that it first becomes wrinkled and then swells; it absorbs the water. This seems to happen equally well with the micropyle above or below the water. In each case the seed swells. With regard to ascertaining the effect of light and warmth, jars with seeds must be kept in light, dark, warm and cold places respectively, all other conditions being the same, and results noted. Excellent work can be done by children at home, if they soak a small flower pot, sprinkle its inner surface with small seeds—*e.g.*, cress; these cling and will germinate. The pots can then be kept upright, then turned upside down, when they will be dark inside, and later they can be turned on their side. Care must be taken to keep the pot moist. To ascertain whether air is necessary, grow seeds either in a vacuum or in water deprived of air or in harmless gas—*e.g.*, hydrogen.

What makes the roots always grow down, in whatever position the seed is placed ? Is it the water, or darkness, or gravity ? A seedling is suspended in a jar covered with black paper out of which a narrow strip is cut. The root

tips turn down and away from the light. Germinating seeds are put at the bottom of a dry jar and a tumbler containing wet moss is inverted over the jar. The tiny roots turn up, but only for a short time; then they die. An experiment may next be made in which gravity acting on the seedlings is eliminated, when the roots will be found to grow in any direction.

Conclusion: The roots grow downwards in response to gravity, but always away from light and in the direction of moisture. Similar experiments may be devised to ascertain why shoots grow up.

(See also chapter on Aids to Nature Study: The School Child's Flowers grown from Seed.)

5. Winter buds of common trees. Twigs from a few common trees with typical buds might be studied in some detail—*e.g.*, twigs of horse-chestnut, beech, oak, and lime. The lesson should consist chiefly in drawing the twig as a whole and one bud enlarged, without attempting dissection. In the course of description, either verbal or by means of drawing, the markings, such as scars, rings, lenticels, will be found by the children. What are they? It would be well to show them in the drawings and to mark them in some way as points yet to be enquired into. Such drawings, if they are made in nature study books, should be available for future reference. Later, when the bud scales fall away, and still later when branches kept in water meet their doom and the young leaves fall off, two of the problems are solved. The meaning of the lenticels will probably never be revealed by actual experience during the period of the nature study course—some meanings are not revealed for even longer periods. On the other hand, the meaning may be arrived at by reasoning from analogy.

As a matter of course the buds will be drawn at regular intervals of time during the period of their unpacking.

Some of the buds reveal inflorescences, a matter of great

interest to the children. Just because the flower buds are usually numerous, small, green, and round, and are enclosed in a protective covering, the children are inclined to call them seeds. This is one of the interesting examples of the young naturalist's manner of interpretation, and care should be taken not to cut it short by forced reasoning which is in advance of experienced fact.

An unfailing appeal to the pupils' sense of wonder is made when their attention is drawn to a new feature of their old friend the hazel in the shape of a bunch of crimson threads protruding from some of the buds. Country children may be asked to mark some buds of this kind on an actual hazel bush and to see whether anything else besides a leafy shoot grows from such a bud. City children may have to be frankly told that the nuts will form on the shoots contained in these buds. Then what becomes of the swinging catkins ? This will be an entry in the " Unanswered Questions " book, which every class should possess.

The process of the unfolding of a winter bud of trees has been watched, and the pupils therefore know what the buds are likely to contain, but it is a matter for further investigation to determine in what condition the various parts are enclosed by the outer covering, and what the arrangement is within the bud. Dissection of some large buds may now be attempted, the facts observed recorded in drawing and in written reports. (See "Living Creatures," chapter xxv.)

If the general notion of winter bud is extended to plants other than trees, suitable material for a first lesson in the dissection of buds may easily be found. No finer example of close and careful packing of young leaves in a bud than a cabbage could be provided. If the practical work is actually done by the children, Brussels sprouts can be distributed among them. From such preliminary studies it is easy to lead on to the examination of horse-chestnut and sycamore buds, and to some of the larger kinds of winter buds.

Care should be taken that the pupils learn to look upon a winter bud as essentially a structure adapted to the vital necessity of preserving young and delicate shoots from loss of moisture during a time when the work of roots is at a standstill and the supply of water is cut off. Thus leathery and tough scales, gums, down and hairs, overlapping and close packing, are not primarily devices that "keep the cold out," but an effective means of preventing evaporation.

When twigs of trees are kept in water and the buds unfold in springtime to the delight of all the class, then the time comes when growth and progress suddenly cease and decline and death set in. It is with the older pupils of Stage III. that the desire often arises to find ways and means to keep the twigs alive. This seeking for ways and means, involving as it does an enquiry into the conditions of nutriment and assimilation, prepares the way for the work of the ensuing period of study.

6. Life history and habits of common pond animals—*e.g.*, caddis fly, dragon fly, water beetle, pond snails, etc. (See "Living Creatures.")

7. Observations on the bird life of the neighbourhood.

8. Common flowers.

9. Life history and habits of honey bee, ant, cabbage white butterfly.

Stage III

The pupils' attention is focussed on the phenomenon of "aliveness," and their work becomes more analytic in method. Continued observation of plants from seed to seed, of animals from egg to egg or from birth to birth, supplies biological experience of the process of growth and change. Behaviour of the organism as a whole is resolved into the principal life functions—viz., feeding, respiration, excretion, movement, reproduction, vital rhythm. Kinship of animals

and plants with man, in all which is fundamental in living, becomes plain to the pupils.

Throughout the whole time which this stage occupies plants and animals should be under observation, so that the spectacle of growth and change is witnessed. Record charts, in the form of pictures drawn to scale or in the form of graphs, will be suitable means of registering observation and will train the children in the habit of disinterested judgment. Suitable material for this work will be found in growing bulbs, seeds of annual plants, eggs of frogs, newts, and various insects, mice, rabbits, pigeons, etc.

Elements of plant physiology will provide an answer to the children's enquiry into function. It is intended that this work should take the form of a continued argument and should entail practical work for the children, demonstration by the teacher, and general discussion.

There is obviously ample opportunity for associating the knowledge acquired with the facts and needs of human life. A proper correlation should be established with domestic science on the one hand and the principles of hygiene on the other.

There should be an atmosphere of open air and concrete reality about the work throughout the course. The treatment must be vital and dynamic so that the pursuit transcends the classroom and becomes an interest in the pupil's home life. Formal and academic teaching will defeat its own end.

The work must be objective and practical. It must become a discipline in seeing and thinking in consequence of an inquisitive interest kept alive in the pupils. In this way alone will scientific method be realized.

Organized field rambles, whether carried out by the whole class or by individual pupils, must form an integral part of the work, even if they occur only rarely. They serve as a source of inspiration and ensure proper content and per-

spective. Similarly school gardens, even if confined to window or roof gardens, are indispensable as regions for experiment and continued observation.

Use should be made of zoological gardens and museums, not only because in town schools field work is difficult, but for the practical demonstration of systematized knowledge which they provide.

The pupils should have access to books, whether in their own school or at the free libraries working in conjunction with the schools. They should be encouraged to read, and should be given time for this purpose.

The work necessitates a practical room. This need not be a laboratory of the usual type. It must provide space in which to move about freely. It should be furnished with tables which can be easily moved. Good lighting is essential, and it would be of great advantage if the windows were built out so as to form conservatories for plants. The room should have cupboards and shelves for simple apparatus and reagents, several sinks, and adequate water and gas supply.

The work entailed by this course can be adapted as regards range to the needs of the school. Obviously the more time is spent upon it and the wider and richer the experiences are for the children, the more certainly and effectively will it prepare for life after school.

At this stage in a scheme of nature study every opportunity should be given for individual work. In the course of the earlier work the pupils will have acquired the habit of satisfying their curiosity by enquiry and thorough observation. They will have learnt to appreciate the ways of nature and will treat plants and animals with care and consideration. On the whole, the pupils prefer to work in groups of like-minded individuals, and such groups may be organized to pursue some particular line of enquiry. The groups should keep each other informed on the nature and results of this

work. The teacher will have the difficult task of providing favourable conditions for the work of the young scientists. He must "foresee" what apparatus and material will be required, but, above all, must he act the part of "guide, philosopher, and friend." He alone can create the right atmosphere for the work, inspiring his pupils with his own love of nature and with his knowledge.

Suggestions for Stage III. Syllabus

Assuming that the work in the main represents the individual interest of pupils or groups of pupils, and their own choice, it follows that no definite syllabus can be planned. Nevertheless, certain topics may be mentioned as having been found profitable in the study of "aliveness," and at the same time attractive to young students. The following topics have been found to provide ample scope for individual enterprise and study:

1. Classification of fruits and seeds according to structure, including the making of models. (See "Living Creatures," chapter xxv.)

2. Study of earthworms, repeating with modifications some of the experiments recorded in Darwin's "Vegetable Moulds and Earthworms."

3. Biological study of the soil—some factors in the formation of a grain of wheat.

4. Simple experiments in plant physiology on the lines of the notes on Breathing and Feeding of Plants (see Aids to Nature Study, page 80).

5. The aquarium. Special study of water plants. Balance of nature. Life and habits of the less common aquatic animals. (See "Living Creatures.")

6. Flower pollination. (See "Living Creatures," chapter xv.).

7. The inter-relation of animals and plants.

SECTION III

AIDS TO NATURE STUDY

I. KEEPING ANIMALS IN SCHOOL

A CHILD who has intercourse with nature in his normal everyday life acquires wisdom both by extensive and intensive experience. He plays in the garden, roams through fields and woods, sees new sights and hears new sounds, some of which arrest attention but for a moment, and others make impressions that last for a lifetime. Some of the treasures that nature presents awaken so much interest that the child will go again and again to the place where they are displayed, and watch their growth and consequent change; and other things, especially some animals, by their pleasing appearance and winsome ways, call for the child's affection and arouse his love of possession and close companionship. Such creatures frequently become " pets," and the care for their comfort and welfare while they are in captivity constitutes one of the child's earliest as well as most genuine responsibilities.

It is the endeavour of teachers to model the activities in school on the affairs of real life. It is true that this is not always possible, and with regard to nature study especially, circumstances and conditions of city life make it almost impossible to give the little ones opportunity for exploring the world of nature which is their rightful heritage, or to watch some living thing in its natural environment passing through the phases of its existence, or even to play with and care for little fellow creatures that have become pets of the household. All the same, every effort is made in nature study teaching that the children shall not be entirely deprived of some of the most valuable means of development and education. Our syllabus presents a variety of seasonal topics for study, and by providing as liberal a supply of material from gardens,

fields, and woods for the children to work upon as is possible, we can, to some extent, ensure habits of observation and a widening of the circle of acquaintances. By growing bulbs and seedlings on our own tables and window-sills, and displaying jars of twigs with unfolding winter buds, and aquaria containing frog spawn yielding beloved tadpoles, we can give opportunity for continued observation of the phases of individual development. Finally, attempts are even made in some schools to keep pets for the children, so that the latter may learn to care for animals who have become their companions. Although the wisdom of this plan of action has been questioned, where schools are overcrowded and competition for fresh air and space is already keen, there is no doubt that, where favourable conditions prevail, as, for instance, in many well-established kindergartens and other junior departments of schools, much is to be said in favour of this means of training.

Whichever aspect of nature study, outlined above, is to receive attention, it is necessary to keep animals in at least temporary confinement from time to time. The problems of providing accommodation and food are often found extremely difficult. It is in response to many enquiries that the following pages are written. The hints supplied are not in the nature of "the only way," but mere descriptions of ways and means that have elsewhere been found useful, and which are capable of modification to meet particular needs. It goes without saying that the element of cruelty which is inevitably involved is only reduced to a minimum if the creatures are conscientiously attended to, and should little children be responsible for their care, then supervision by a responsible person is indispensable. Scrupulous cleanliness is essential at all times, and the supply of food must comprise water in almost every case. Indeed, water is so absolutely necessary for healthy living, that many creatures perish unless earth, sand, moss, grass, and

other equipments of the "cage" in which they are kept, are all in a moist condition. Finally, we can hardly lay sufficient stress on the educational value—which alone justifies the enterprise—of making the outfit of the case as attractive and beautiful as possible. To make a glass jar which contained chrysalids of some butterflies and eggs of the silk moth also contain some pieces of chalk and drawing pins; to throw withered flowers for the time being into the aquarium till they revive; to fix untidy labels to cases—are all unlovely practices which defeat much that nature study tries to establish. The haunts of the creatures in their wild state have elements of beauty, and to withhold those means losing a golden opportunity for the æsthetic training of the children.

The following notes and directions are arranged according to the main groups of animals that may be studied during a nature study course of a city school. The care of birds in captivity is omitted in this description, chiefly because keeping feverish wild birds of great sensitiveness imprisoned is contrary to the spirit of our teaching, while other birds, such as doves, pigeons, canaries, etc., which are domesticated or bred in captivity, are so well known as regards their needs that no reference need be made to them.

1. **Hedgehogs, Rabbits, Guinea-Pigs, Rats, Dormice, and other Mice.**—For all these creatures cages are required; these consist chiefly of wooden boxes suitable in size for the animals in question to have sufficient room for exercise and enterprise. One part of the box should be partitioned off for bedroom accommodation and general retreat. A suitable opening must be made in the partition for easy communication between the two compartments. In the case of rats and mice which breed freely, and of which more than one generation can be kept in the same cage, it is essential that several bedrooms are provided, either all on "the ground floor" or one above the other. In the case of guinea-pigs

and rabbits, every mother with young should be kept in a separate cage. As regards hedgehogs and dormice, I have never heard of their breeding in captivity. All these animals, except hedgehogs, being gnawing animals, it stands to reason that their cages must be made of comparatively thick boards and well joined. In order to admit light and air, the wood must be cut away in places and replaced by wire netting, perforated zinc, glass, etc. I have found it useful to fix strips of perforated zinc wherever I found signs of the gnawing propensities of my pets. It can easily be cut with shears and fixed with drawing pins or tacks. As sanitary conditions are absolutely essential, it is advisable to prevent the floor of the cage from becoming saturated by excretion. In the case of rats and mice this can be ensured by a liberal supply of sawdust, which is absorbent, and if from pinewood, even antiseptic. A small quantity of sanitas or other disinfectant powder, mixed with the sawdust, prevents unpleasant smell. With regard to the larger animals, a sheet of tin or zinc, exactly fitting the floor space and covered by a layer of sawdust, ensures cleanliness. It stands to reason that for purposes of cleaning at least the lower part of one side of each compartment should form a door, but if the little captives are not tame, smaller doors must also be made, only sufficiently wide to introduce food and water. The bedrooms must be provided with some kind of nesting material. Hay is most suitable for rabbits, guinea-pigs, and hedgehogs. The former two kinds of animals generally eat their bed, and have to be supplied daily with fresh material. For rats and mice a variety of material is often worked into one mass—*e.g.*, dried and broken fronds of bracken, hay, wool, cotton wool, paper, etc. As these animals keep their bedrooms very clean, they should not often be disturbed.

Both rats and all kinds of mice, especially dormice, should be supplied with opportunities for climbing, either in the

form of stairs and galleries or branched bows of trees wedged firmly into the cage.

The food for these animals is easily obtainable. Green-stuff in the shape of grass, dandelion, lettuce, and cabbage, is suitable for guinea-pigs and rabbits, although it must be given in moderation if the animals are to be kept indoors. Carrots are excellent, and bran and oats mixed are suitable dry foods. The hedgehog must be supplied with small pieces of raw meat and with bread and milk. Rats will thrive on bread and milk, cheese, biscuit, grains, and hemp seed. Mice should be supplied with bread and milk, biscuit, shelled nuts (monkey nuts, chestnuts, and cobnuts), and apple. Dormice must have a liberal supply of whole nuts, as they can easily rasp a hole in the shell and gnaw the kernel, and woodmice will do the same. Nuts and apples alone, with an occasional fragment of biscuit or some hemp seed, are suitable food for dormice. As regards the supply of water, this must be attended to very specially when neither milk nor juicy food is supplied.

I have on several occasions been presented with moles, and hoped to be able to keep them in confinement, so as to be able to watch their interesting habits. I kept them in very large fern cases, admitting plenty of air, and containing a deep layer of mould. They all took worms readily, and in large numbers, but they died within the day, possibly from fear.

2. **Tortoises, Lizards, and Snakes.**—Tortoises and turtles are sluggish creatures and show little signs of response to affectionate treatment, nor do they stimulate observation and enquiry, as their habits in this climate are demonstrated but rarely, and are of an unvarying character. A tortoise is at its best in this country if kept in a garden and allowed to roam freely, where it may cause a stir of excitement by clearing a bed of young lettuces and burrowing in a seed bed. But if it is kept in a box and indoors it leads a dreary

existence. The box, if deep, need have no covering over the top, as the animal can only escape if it can place its front feet on to the top edge and heave itself out. At the bottom of the box there should be turf and a hiding place made of tilted stone, or the large pieces of bark which are used for covering window boxes. At the approach of winter, special care must be taken that it has a hiding place for the period of hibernation. A similar abode should be provided for the water or pond tortoises which are sold more frequently than the land tortoises by dealers in animal life in the streets. As the name implies, this creature has aquatic habits, and must be supplied with a trough, or deep bath or tank in which it can swim. If, on the other hand, it is kept in an aquarium, a large bank or island must be constructed for its land wanderings. Both kinds of tortoises like sun and warmth in which to bask, but the pond tortoises are most active at night-time. The land tortoise is fed with fresh young greens, but the water tortoise is carnivorous. Its natural food is aquatic larvæ of insects, tadpoles, small newts, fish, and worms. If kept in captivity it must be fed with food of this kind, but occasionally a tortoise has been known to feed on small pieces of raw meat. As regards its more natural food, most people have least compunction in sacrificing worms. It must, however, be remembered that the worms crawl away and hide in the turf, and the tortoise remains unfed. The best plan is to place a number of worms every evening into a wooden box with lid, and put the pond tortoise also into the box. It must be left for about an hour perfectly undisturbed. If the practice is not successful the first few days, it should, nevertheless, be continued, as the hungry tortoise may learn a lesson and develop a habit for which it had at first no inclination.

A similar box answers well for a cage for lizards and snakes, but if a fern case or terrarium is available this should be used, as it admits much more light. It may have turf at

the bottom or fibrous earth, such as is found on moors. A few flower-pot saucers containing clumps of short grass and moss, well supplied with moisture, may be partly imbedded in sand or earth. Flat pieces of stone tilted over each other must form nooks and crannies. When the sun shines the lizards will frequently sit on the stones, but they are inclined to hide in dull weather. Of the snakes, a small specimen of the grass snake is probably the only suitable kind. As this snake is fond of water, however, it must be supplied with a shallow tank within the terrarium.

Lizards must be provided with live flies, which must be put into the cage in considerable numbers. To supplement the daily supply, it is convenient to buy "gentles" at a shop selling fishing appliances, and to put them with some moist sawdust into a small tin box and to keep the lid on it. In the lid there must be a hole so that the flies can escape as they emerge from their chrysalis stage. This little box placed in the lizard's home will be a source of food supply. The gentles themselves, as also mealworms, are suitable food, but as they naturally crawl out of sight, the same method may have to be resorted to as in the case of the pond tortoise. The only food which snakes will take is live frogs, and as little frogs have a very warm corner in the hearts of teachers and children alike, we are not very willing to sacrifice them in cold blood. Besides, the manner in which the frogs are caught by the snakes can only be witnessed by one who possesses the temperament of a stoic, and of these there are but few. As snakes can quite well do without food for several days, they might be kept in the classroom, and in captivity for only a short period, until the children have had opportunity of watching their beautiful movements, and then they might be set free to do their own hunting. Lizards, too, should not be held captive long, as they do not thrive well in the limited amount of sunshine that our classrooms admit.

3. **Frogs, Toads, Newts, Salamanders.**—Although glass cases with perforated zinc tops and fern cases are by far the most attractive and suitable homes for these creatures, the wooden box can provide every comfort. The disadvantage of the latter is always the fact that the supply of light is inadequate, at least for the purposes of our observations if not for the creatures' welfare.

The bottom of any terrarium containing these moisture-loving animals should always be turf, the grass being kept short with scissors. Moss can also be used, but as it does not live in this condition it soon discolours and becomes unsightly, whereas turf keeps fresh and green if regularly sprinkled with water. If the wooden box is used the turf should be kept in a baking tin imbedded in a layer of earth, as it can thus be supplied with water without causing the wood to warp. A large flat dish of water must be imbedded in the turf or earth, so that the animals have opportunity for swimming. Toads, newts, and salamanders, which are more or less nocturnal in their habits, tend to bury themselves entirely under the turf, and the children can never see them without disturbing their home. A simple device may prevent this. A piece of wire netting of small mesh can be cut to cover the whole of the turf at the bottom of the terrarium, coming close to the edge of the tank. It should be well pressed down on to the turf. In a few days it will be entirely hidden by the grass growing up through the netting, yet none of the creatures can burrow. We must, however, recognize their need for seclusion and make cosy hiding places with piled-up stones, which the children can easily lift when they want to peep at their pets.

Frogs, toads, newts, and salamanders are most easily fed with gentles and earthworms in the manner described in connection with the feeding of pond tortoises. It will be found that newts take very little food at a time when they live on land, and are therefore housed in the terrarium.

During the breeding season their home is in the aquarium, where they feed voraciously on worms and tadpoles.

4. **Fish, Aquatic Insects.**—The home of these animals is represented in our classroom by the aquarium, which has long ago established itself as one of the most fruitful means of nature study. The construction and care of an aquarium are fully dealt with in Section III., The School Aquarium, and information has been given regarding the feeding of the inmates.

5. **Insects, Millipedes, Centipedes.**—Many little creatures are sometimes found in sufficiently large numbers that a nature lesson may be given on them, adopting the method of class teaching. Enough ladybirds may sometimes be found during a single ramble, or if the teacher is working an allotment that was covered with turf only a year ago, enough wireworms may be found during a single week-end to meet the requirements of a large class. Another method of procedure is now adopted in many schools. Instead of the whole class having specimens of the same kind of animal, a large variety of little creatures found on plants and in the ground are brought to the classroom and kept for the nature lessons. During the latter each child is provided with a specimen, introduced by its name, and the children either singly, or working in pairs, make their own observations, recording them by notes and drawing. It may be possible for children to exchange specimens during a subsequent lesson. Whatever method of procedure is adopted, it is essential that the animals are in suitable receptacles, and may be kept in them for some days. A set of flat glass-topped tins about 2 by 3 inches or 2 to 3 inches in diameter is an excellent addition to classroom apparatus; the rectangular tins look better, but the round ones have no joints at which small creatures can often escape. These tins can be fitted with a layer of plaster of Paris, which retains moisture without being wet. If this is not convenient, a

piece of clean blotting-paper, kept moist, answers the purpose. In these tins the little animals can be kept, provided all along that some food is given to them. Thus green fly must have some young leaves, ladybirds a spray with aphides, wireworms and many beetle larvæ a seedling, and so must leather-jackets. Other beetle larvæ and beetles must have tiny worms, and the same is necessary for centipedes. Millipedes, on the other hand, must have a morsel of bread or potatoes. The tins contain quite sufficient air, but care must be taken that fresh food is supplied when necessary, as it is apt to spoil quickly in the moist atmosphere.

As regards larger insects and their metamorphosis a few words must be said. Caterpillars can be kept in a variety of breeding cases, according to means and opportunities. Any boxes with one or more sides removed and net or coarse muslin pasted over the space answer the purpose well. The most important point to remember is that the food plant should be provided in a fresh, not wilted, condition. It is best to arrange that the boxes stand up on end and that the leaves are put in a little bottle filled with water, the neck being well plugged. The caterpillars will crawl up the fresh leaves and browse on them.

Stick insects feeding on privet can be reared on their food plant growing in a flower-pot, or branches of it stuck into the moist earth. By means of a number of sticks put round the plant, and a piece of muslin tied over the sticks to the rim of the flower-pot, an airy home will be provided. In all such breeding cases chrysalids can be kept until the butterflies emerge and the doors are likely to be opened to them.

Humble-bees and wasps can well be kept in captivity for one or two days, and the children might have opportunity for noticing the difference in their mouth parts and methods of feeding. A few flat flowers, such as ox-eye daisies, are put in a small bottle of water, and the whole is placed into a tall glass jar, or glass case in which the humble-bees have

been put. A mixture of honey and water is made, and a few drops of this liquid are carefully placed on the flowers. A little more may be placed in a watch glass, and strips of wood or pieces of straw put across it by way of bridges. This is also put in the glass case. The bees will readily find it and stretch out their "tongues" to the delight of the children, and if the flowers are suitable, the bees may even get their coats dusted over with pollen. A similar arrangement will afford a house for wasps, but it is not necessary to dilute the honey, as it has not to be drawn up through a long "tongue." Quite different accommodation would have to be provided for wasps' and bees' nests, but these are not as a rule kept in a classroom while their inmates are at work.

6. **Snails and Earthworms.**—These lowly creatures are frugal in their wants. It is, above all, necessary that they are kept in moist surroundings. The box mentioned so often, furnished with turf and covered with a sheet of glass, provides a satisfactory home for snails, and boiled potatoes, cabbage, lettuce leaves, their normal rations.

Worms are most conveniently kept in glass jars or inverted bell jars, filled with earth and tied round with black paper. A sheet of glass must cover the top, as even worms may wander. The worms will make some of their burrows along the sides of the glass, so that they may be seen when the paper is removed, and castings will be deposited at the top. If layers of differently coloured soils are put into the jar, the process of ploughing and churning which goes on so extensively in nature may be witnessed in the classroom.

Space has not permitted the treatment of the subject in any great detail, and many a possible nature study specimen has been omitted from the list, but if the less experienced teachers have derived some help in this difficult task of bringing treasures of nature within the reach of city children, the purpose of these notes is achieved.

II. THE SCHOOL CHILD'S FLOWERS GROWN FROM SEED AND BULB

Autumn is the season of fruiting, and as autumn merges into winter, a wave of decline and death passes over the plant world. Through their fruits and buds and bulbs the dying and sleepy plants contribute their share to the glories of the coming spring. The seeds within the fruits are scattered in many different ways: the wind helps most, and in the case of the plants growing by the banks of streams and ponds and in the water itself, the currents and ripples carry the seeds to other parts. In some instances the fruit case bursts open with force and the seeds are jerked a considerable way; then there are the furry and feathery inhabitants of wood and field who unconsciously become aids in seed dispersal.

This is how things are arranged in the household of nature; uncertain agents like wind and bird and the flowing wave are concerned in seed dispersal—hence much loss and waste. Great lavishness is noticeable, and prolific seed production, and this certain result that every species of plant is represented again in the pageant of next season's flowers. This order of things became somewhat changed when man took matters in hand. Many plants serve man as food, others are used in making clothing, others are valuable to him in other ways, and so it came to pass that he bestowed special care on these plants. It was also a matter of inconvenience to him that wheat and others of his pet plants should appear in little patches here and there, and the patches should be separated by communities of other plants. Thus it further came to pass that man started to collect seeds from brown and yellow dying plants, to save them up carefully, and in due season to sow them in fields specially prepared for the purpose. The idea of taking the seeds from the ripe

fruit cases and putting them into the ground was obtained by watching what happens in wild nature.

The seeds were put into specially prepared ground. In what way prepared ? The ground was cleared, all plants on it being uprooted and removed, then dug deep, and each shovelful turned over. The lumps were made small and fine, then the seeds were put into the ground, either singly in little pits if the seeds were large, or strewn in furrows or evenly all over the field. In every case the seeds were covered over with a thin layer of soil. How has man come to know all this ? See, the seeds carried away from the old plants fall to the ground sooner or later. Many fall on rock and are eaten by birds, many fall on stony ground and cannot take root, and many fall amid big strong plants that smother the striving seedlings; a few fall on soft open ground and flourish. Again, there is much waste. Of all the children of a buttercup only a very few become adult buttercups. Man noticed just what chances these few plants had, and gave his whole sack of seeds the same fair chance. A very much larger proportion of seeds grew up and flourished, and this was to his advantage. But even when the ground is loose and clear the seeds may not grow up—they need warm sunshine and the right amount of rain. Now to supply this is not altogether within the man's control. If his field is, to begin with, wet and marshy, he can drain off the water, but if it rains and rains day after day he cannot do anything; if there is not enough rain he may be able to water a little, but in periods of drought water is scarce, and the labour of carrying water is too great to do it to any considerable extent. Rainfall and sunshine and stormy winds and hail and frost may be a farmer's fortune or ruin, therefore at all times a matter of hope and fear.

Times changed again, and man formed communities and villages became amalgamated and great cities grew. With this followed division of labour, and each man was no longer

his own farmer, hunter, tailor, builder, etc., but some did one thing and some another.

But although we city folks have no fields to cultivate now, there is one thing we have retained ever since those days, and that is our love for something green, growing and blossoming, and so we have laid out our gardens even in our cities, and if it is only a little back yard, we like to see something sprouting in it. Where the city is densely packed we may not even have that; all the same, we cannot give up this hobby: men and women, boys and girls alike take pleasure in a pot of flowers or ferns in the room, even though some of us can hardly spare the time to see to it.

Supposing you can spare a few minutes every day, and a bit of a window sill or ledge, and supposing you have saved up a few pennies, and supposing you would very much like to have something alive and green about you, and supposing you would further like to understand a little more about the seeds and their way of growing, read the following pages, and see what you can do and learn.

From what has been said before, we realize that we want to consider the following things:

1. Seeds.
2. Ground, or soil, and pots.
3. Sowing.
4. Care of seedlings.

Now in some ways we are better off than the farmers were in olden days: our plants can be taken indoors, and so there is no fear of hail or frost, or great storm, or too much rain, or too little water, if we attend to our pots carefully, and we can choose good seeds and good soil, and so one would think we ought to produce the best plants possible. As a matter of fact, we do not produce very good plants, and only a few kinds are at all satisfactory, simply because our city air is not fresh enough, especially in the houses, and our window ledges are draughty, and because our window only

lets in a little light and only from one side, and this matters very much. Still, the game is worth the candle, and beautiful things have been reared in city flower-pots, provided all care has been bestowed on them.

1. **Seeds.**—It is all-important that the seeds should be obtained from a thoroughly reliable source. In a complete list of our garden plants, such as is issued by many seed specialists, a short description of the plants is given; also the quantity of seeds that will be supplied in each small packet. In most cases, far more seeds are contained in one packet than can be planted in a pot; it would therefore be advisable for two or three pot owners to join in a packet and share expenses. In the case of heads of schools taking up the matter and ensuring a large order, there is every reason to believe that expenses will be materially reduced. The following is a list of seeds that have been found to produce good results when grown on window ledges of city dwellers:

Marigold (African).
Calendula (Scotch Marigold).
Candytuft.
Mignonette.
Stock—Ten-Week.
Pansy.
Nasturtium.
Virginian Stock.

2. **Soil.**—It is equally important that good soil be supplied—coarse clayey soil mixed with street dust is absolutely useless for our seedlings. The best soil is a yellow fibrous loam mixed with a little silver sand, and a pennyworth of these may be obtained at any shop where gardening appliances are sold. If the school takes up the matter a large quantity may be obtained from certain firms for distribution.

As regards pots, ordinary earthenware flower-pots are best; they have a hole at the bottom and are porous; this

means that water inside is not left standing, but much of it drains off through the hole and some escapes as vapour through the sides—air also can penetrate the soil. All this is important, as want of aeration and stagnant water are conducive to decay and rotting in seeds and seedlings.

If flower-pots are not available, small strong wooden boxes answer the purpose very well, but care must be taken that the surplus water can escape, and some holes should be made in the bottom. They should also be raised off the window ledge or ground by a few pieces of firewood so that air can get under, else the bottom will rot. Flower-pots should have a few broken pieces of crockery over the hole, and a layer of stones and crockery should also be put in the bottom of the boxes. Then the pots and boxes are filled with the light, slightly sandy soil that has been prepared, but not right up to the top—why not ?—but, on the other hand, it must come to about one inch from the top edge—why so high ? Care must be taken that the soil is fine and contains neither lumps nor stones.

In one school the experiment has been made of asking the children to provide small wooden boxes, such as cigar and chocolate or soap boxes, to represent a garden. The children strengthened the corners of the boxes with strips of wood cut from the lids; these they nailed on in such a way that all the corners of the box were supported by strips; thus there were two strips at each corner. Since the grain in the wood of the strips lies at right angles to the grain in the wood of the sides, warping is prevented. If the strips are cut a little longer than the vertical height of the box and are allowed to project below, they will raise the box from the ground, and drainage will be facilitated. It is not necessary to make holes in the bottom, as the box is in no way watertight. The children painted the boxes in various colours of varnish paint, chiefly to obliterate trade and other marks, which were unsightly for a garden.

3. **Sowing.**—This event should take place about April Early in the month Scotch marigold, mignonette, ten-week stock, pansy, and nasturtium should be sown; later, African marigold, candytuft, and Virginian stock. If the flowers are wanted for a school show in July, candytuft and Virginian stock, which flower early, had better be sown again in another pot in May and early in June, in order to ensure having flowers in July.

Now comes the important act of planting the seeds. The farmer scatters his seed broadcast over the field, and we sprinkle them evenly over the surface of soil in our pot. This applies to all fine and small seeds. The larger seeds, such as peas, beans, and nasturtiums, we push into the soil to a depth of about two inches. Of these large seeds, not more than three should go into a medium-sized pot. Next we sprinkle a thin layer of fine soil over the little seeds, and see that our large seeds are well covered also. When this is done it is important that the seeds be watered. Until the seedlings come up, water should not be poured over them —why not? The pot should be stood in a basin of water, so that the water comes up to about half the height of the pot, and should be left in the water till the soil looks damp all over. The water should not be quite cold. The case is somewhat different with boxes, which, naturally, cannot be left standing in water. A good plan is to lay a piece of blotting paper or thin cotton rag over the soil, and then to pour the water gently on this. If neither blotting paper nor cloth is available, the water may be sprinkled on with the hand.

4. **Care of Seedlings.**—When the seedlings make their appearance, water may be given to them from the top in a very gentle shower. The pots should be kept out of doors, say, on a window ledge. It is a good plan if pieces of glass can be procured to keep the pot covered until the seedlings are about three-quarters of an inch high, but this is not

actually necessary except in the case of African marigold and pansy and ten-week stock. With regard to these plants, it is better to keep them indoors, and under glass until they are thinned out.

After the seeds have been sown and watered they probably do not require water again for two or three days, especially if they have been covered with glass. It is very important that the seeds and seedlings are not kept actually wet, only damp, else they decay. Exact directions cannot be given in this respect, as it depends on the temperature and wind whether the soil dries up quickly or not. When the glass is removed and the box is out of doors, it will probably be necessary to give about half a teacupful of water every second day, but the rule should not be implicitly adhered to—common sense should decide the matter. When the seedlings are about one inch high we have to perform a very unpleasant task; so hard is it that many owners cannot bring themselves to do it, and the result is failure. The seedlings must be thinned out, all except those springing from large seeds, of which only three or four were put into the pot. Thinning out means pulling up carefully all the weaker seedlings. This must be done from time to time until you have only a very few plants left—three to five, according to size of plants and pot. When small seeds are sown, the fingers have not sufficient control over their movements, and far too many always fall upon the ground. They come up very thickly, and they can neither spread out their roots underground nor their leaves above ground. Consequently they cannot obtain sufficient food and light, both of which are essential to their life and growth. It is, therefore, better that some are pulled up so that the others have a chance, than that all should suffer. This is the reason why the process of thinning must be carried out. Pansies, African marigolds, and ten-week stock should be treated as follows: When the plants are about one inch high

a few of the healthiest are taken up, root and all, with a teaspoon, and are planted in another pot or box, so that they are two or three inches apart. They should be kept indoors for about another week and then put out of doors.

If the good soil mentioned was not procurable, it will be found necessary to give the plants a little artificial manure once during their growth. Clay's fertilizer is best; but it must be used sparingly. All through the time that the plants are growing and developing the one thing needful to give them is as much air (but not draught) and as much light as possible, and to keep them evenly supplied with moisture. The water that suits them best is the rain as it falls, but in a heavy rainstorm the seedlings should be under cover.

Beyond this we can only hope and fear, as man has at all times done with regard to his crops, but the pleasure of having something alive of our very own, something that needs our attention and care, is ever real and worth striving for.

Bulbs in School

The influence of cheerful, pleasing, and interesting elements in our classroom on the children's mood and on our own is undeniable. We desire, therefore, to have flowers in vases and various flowers growing in pots on the window-sill. Sometimes this desire is fulfilled. As regards growing plants, much disappointment is experienced because many of our favourites do not thrive under ordinary classroom conditions, especially if the school be situated in a city street. By far the most satisfactory results are obtained if bulbs are grown instead of geraniums, ferns, and the most depressing aspidistra.

It is chiefly, however, as a form of nature study that the planting and culture of bulbs is recommended. Not all kinds of bulbs thrive equally well, and even the hardiest

ones seem to resent the weakening influences of life indoors. Daffodils grow most easily, and tulips and hyacinths are also suitable. The following varieties have actually been grown under trying circumstances and can, therefore, be recommended:

Daffodils.—Golden Spur (self-coloured, very early), Emperor (rich yellow trumpet, pale perianth, early), Sir Watkin (large flowers, short yellow trumpet, pale perianth), *Poeticus ornatus* or Pheasant-Eye Narcissus (trumpet reduced to cup with red edge, perianth white).

Tulips.—Duc Van Thol (scarlet, early), La Reine (pink), Mon Tresor (yellow).

Hyacinths.—King of the Blues (dark blue), Grand Maitre (pale blue), Gertrude (rose), Baroness Von Tuyll (white).

It is best to plant the bulbs during October and November, making the process of planting a subject of study. They will flower in the spring term, when the nature lessons will be occupied with the study of growth.

Autumn Lessons.—Acquaintance should be made with several kinds of bulbs, learning to distinguish one from the other, and recording their observations in coloured drawings, to be kept for future reference. The relative size of the bulbs should be noted. If the children's previous experience of growing plants indoors is revised, their statements probably represent a body of facts relating to plant culture, handed down from generation to generation. The traditional process may now be made the subject of enquiry and the lesson conducted as follows:

Red, unglazed, earthenware flower-pots are generally used. Reference to be made to cheap production of these pots, experiments to be performed to demonstrate porosity, so that both water and air can pass through, a fact of advantage to a living plant, hence the need of keeping pots clean. The shape of the pots is considered. Pots of no

other shape can be packed and carried so easily, and as they stand in rows air currents can pass between them. The hole at the bottom allows for the outflow of excess water, preventing the soil from becoming waterlogged. Stagnant water in the pots makes the soil " sour." The decomposition of organic particles in the ground when the air is displaced by water causes accumulation of acid gas, poisonous to the plant. Moreover, the air between the soil particles itself is needed by the roots and by soil bacteria for adequate respiration. A piece of broken earthenware, shell, stone, or other material is placed over the hole, also a few sticks or cinders. This arrangement will prevent the soil from being washed out, and will not interfere with effective ventilation and drainage. Soil is put into the pots. If circumstances allow, this should be good loam with a little leaf mould and gritty sand. The reason for this selection should be determined in a subsequent year, when soil may be studied experimentally.

The soil is to be placed in the pots. The children should determine the height to which the pots should be filled, considering that the top of the bulb should be about half an inch below the rim of the pot. After the bulb has been placed in the pot, due consideration having been given to the importance of putting it " the right way up," the pot is filled to the top of the bulb, the soil being pressed down firmly but gently so that it does not cake together, the requirements of ventilation being always remembered. The children should determine by experiment and reasoning why it is decreed that thou shalt not in thy earth lust erect a mound of soil on the top of the pot, and thou shalt not fear the earth and keep the pot but half full of soil. It will then be seen that the laws are good.

The soil should be moist but not wet. When the bulbs are safely in the pots, we are told to put them in the dark. Discussing this matter with the children, considerable doubt arises as to the necessity of the process. It is most important

that vigorous root growth shall take place before the shoots elongate. Roots grow best in the dark, but as they are in the soil they are already in the dark, and this need does not come into consideration. Why, then, do gardeners place their pots of bulbs in the dark? It is best to keep the bulbs out of doors or in some cold place, so that the shoots do not grow until the roots are well developed. In that case they would be covered and thickly surrounded with ashes or fibre to prevent them from being injured by frost, and they would naturally be in the dark, and so we may have come to think that darkness is essential. When the shoots begin to develop they grow up through the covering of fibre, all in the dark, before they make their appearance and unfold flowers. Perhaps this is of importance. We do actually find that when bulbs are planted near the surface and the shoots can unfold when they are still very short, there is little or no flower stalk, the flower head is close to the soil in a crippled condition. Then, why did we not plant the bulbs low down in the pot? The requirements of the roots have to be considered in answering this question. We see, therefore, that it is well to put the pots in the dark to ensure the proper elongation of the shoot. The mistake is frequently made that the pots are put into airless cupboards and drawers in the classroom for want of a better place. Remembering that the bulb is a living thing and must have air, the children might invent a method of keeping the shoot in the dark while the pots are still on the window-sill. How would a very small flower-pot answer, placed over the top of the bulb, or a cone-shaped cap made in the hand-work lesson out of brown paper?

If the pots are packed in fibre, they probably need not be watered, but if they are kept in the classroom the soil dries up and water must be given. There is no rule as to the amount of water to be given; the process just requires common sense and self-control. Water should never be

poured on the top of the bulbs, as it is likely to penetrate into the bulb and cause it to rot. The children should by experiment—water rising in soil—learn that plants can be watered upwards. It will depend on the temperature of the surrounding air how long it will be before the shoots appear; the colder the room, the longer we must wait, but the healthier will our plants be.

This rational review of a traditional process conducted with young children will have made clear the fundamental principles of bulb planting, so that when planting time comes round again, the children, now older, need only remind themselves of the facts, and they can plant bulbs for class-room or home without much guidance or supervision. The range of their experience should, however, be extended.

Considering all the lovely and interesting structure that in the previous year had "evolved" from the bulb that was buried, the question was probably asked whether all the stems, leaves, and flowers had already been packed away in the bulb or had "taken form" from formless living tissue. This would lead to an examination of bulbs, for which dissection is necessary. To avoid destruction of things cherished by the children, old waste bulbs should be obtained for the purpose. All observations made should be recorded in drawings and models.

The practice of growing bulbs in glazed ornamental bowls and pots might be considered. The class will note that the porosity of the pot material is rendered ineffective by the glazing. The hole at the bottom is absent, and there is no drainage. The children must find out how these defects are made good. They note that coarse sand or fibre is used instead of soil, with much larger air spaces. They note that shell particles and charcoal lumps are mixed with the fibre sold by dealers, and it might be demonstrated how acidity and unpleasant smells can be prevented by these additions.

Bulbs, particularly hyacinths, grown over water in specially

constructed glasses afford opportunity of making observations on root growth. The glass should be filled with rain-water, and a lump of charcoal should be placed in the water. The level of the latter should be immediately below the bulb. It is important to keep these glasses in the dark. Why?

Winter and Spring Lessons.—The phases of growth of the bulbs from the appearance of a little yellowish shoot appearing above ground to the opening of flower buds and the subsequent vigorous growth of leaves can best be recorded in a series of pictorial drawings which chronicle all the events. These drawings may be inaccurate as to detail, strongly affected by subjective elements characteristic of very young children, or they may be more precise and impersonal statements of observed fact. Simple graphical records are strongly recommended. A large sheet of drawing paper is headed "Tulip Chart" in best lettering. Then near the bottom a horizontal line is drawn. This represents the level of the soil. The sheet is divided, according to requirements, into four or six equal spaces by vertical lines. These represent weeks of life. In each week the shoot is accurately drawn in its appropriate place. To ensure accurate judgment of length, irrespective of mood, the shoot is measured with a piece of cotton and the length marked off above the ground line. Between the latter and the point marked the shoot is drawn and painted. Several of these graph sheets may be necessary to record the pageant of a long life. The wonderful discovery will be made that if a child is absent for a week or two and no records are made, he can in all probability fill in the empty spaces with some accuracy by critically examining the rest of the drawings on the sheet. How can this be done?

This work represents a long series of lessons, practical and scientific in character, and possible for those schools for whom the acquisition of material for study presents insurmountable difficulties.

III. THE SCHOOL AQUARIUM.

In our city schools and city homes, our nature study is, of necessity, practised upon plant and beast and stone, each snatched from its surroundings, each separated away from its context; it is difficult to estimate the loss to us sustained thereby. The very treasures that lie before us on the ink-stained, brown desk in the musty, dusty schoolroom have left one element behind them, "with the sun and the sand and the wild uproar," and are only half real, only partly natural. We cannot emphasize this fact sufficiently—viz., that things natural removed from their environment lose much of this very "naturalness" and become a distorted representation of their own selves.

It is our heart's desire to get to know things as they are, and this desire can only be gratified at all if we behold them in their setting responding to the stimulus of their environment. This condition is fulfilled every time that rambles are undertaken into fields and woods and where the water flows.

The remembrance of what is seen on these occasions will not only form a right background for the detailed study of isolated specimens in the classroom or at home, but will furnish many a clue to problems which present themselves in such detailed study. If these rambles are few and far between, much can be done by retaining a few of our treasures in as natural a way as possible. However humanely and sympathetically this is done, we cannot close our eyes to the fact that it involves a certain amount of cruelty, and every keeper of wild things, be he great or small, should be aware of his responsibility, and should see how he meets it. We may refrain from keeping a feverish, fast-living thing like a bird or a squirrel in a cage, but most of us have much less compunction in retaining some of the smaller, lower, and often more sluggish creatures in captivity, as in such cases

cruelty is reduced to a minimum, provided all along that the captivity is only temporary, and that all the creature's wants are conscientiously supplied.

To the city-dwelling nature student few animals in confinement provide more profitable study than the denizens of the pond. Their peculiar habits and changeful lives arouse interest and curiosity, and stimulate observation They are also easily obtainable, and their wants are few, so that our burden of responsibility towards the creatures held captive is not beyond our power.

The question will at once arise, Which of all the swimming, gliding, darting, hopping, and crawling creatures shall we select, capture, and keep, and how can we best provide for them ?

Since all the most common pond animals come from the same environment, they require similar accommodations; the home provided for them must, in fact, be a miniature pond in any case, showing only such slight modifications as the peculiarities of the particular creatures under observation demand. Let us, therefore, reverse the order of the question and ask ourselves first how we can provide for the wants of pond animals, before we even contemplate their capture. An aquarium should be ready and fit for the reception of the guests some time before they are bidden to come.

Assuming, then, that we have decided to prepare an aquarium, and that we have fixed upon some window-sill or table near the window, where it will stand, we cast about for one or more suitable receptacles. The selection will depend on such circumstances as funds, space available, and actual purpose for which the aquarium is used. Quite generally speaking, globes, bowls, bell-jars, and other jars are considered to be slightly injurious to creatures, on account of the way the light passes through the curved surfaces. But, though this may be true in the case of some of the higher and

larger animals, as fishes and newts, it can make no appreciable difference in the case of the lower creatures, and it may at any time be overcome by suitably shading the sides of the vessel. The only kind of aquarium which it would be well to banish is the orthodox fish globe, as, in addition to its convex sides, it generally is so much narrower at the top that only comparatively a small proportion of the water is exposed to the air. All aquaria, whether made entirely of glass or fitted with a slate or tin bottom, admit too much light, but by shading one or more sides with green muslin or tissue paper, or by keeping the aquarium in such a place in the room that strong light falls upon it from the top or one side only, the right conditions may be maintained. If the aquarium need not be an ornament to the room, nor be under constant observation, all kinds of pottery, such as pudding basins, pie-dishes, or hand-basins, may be used with great advantage, especially for spawn, tadpoles, caddis worms, and other larvæ, and various water beetles. On the whole, it is well to remember that rather low wide vessels form better aquaria than the deep narrow ones, simply because a greater extent of surface in proportion to the whole volume of water is exposed to the air.

Whatever receptacle we may have selected for our aquarium, it will require a foundation of sand, partly to make it look more natural, partly for fixing water plants, and partly also because many animals, such as caddis worms, crawling about on the bottom of the tank, must have a foothold. The sand may be coarse or fine; silver sand obtainable at oil shops, bird sand sold at corn chandlers' and bird dealers', or any river sand may be used. Probably a mixture of different varieties mixed with some pebbles is most suitable. The sand must receive special attention if the aquarium is to be the home of caddis worms, many species of which require heterogeneous particles wherewith to build their cases. The sand must be well washed by being stirred in running

water, and thus freed from the light muddy particles which prevent the water from being clear and often contain decomposed organic particles. The washing of the sand is a troublesome business, but only the most scrupulous attention to this matter will prevent future disappointment. Besides sand and pebbles, some larger stones will be required, so that hiding places may be constructed and anchorage provided for those animals whose light bodies float unless a firm hold be taken of some submerged object.

The tanks being available, the sand and stones at hand prepared, the necessary pond weed should next be procured. This is often kept for sale in fish dealers' shops, but the supply is uncertain, and the specimens often not in a healthy condition—yet the whole success of the aquarium will depend on the vigorous condition of the water weed. Not only do the water plants contribute much to the beauty of the aquarium, and serve as food for many animals, but the general sanitary condition of the aquarium depends on their activity. It is a well-known fact that under the influence of sunlight green parts of plants assimilating carbon dioxide from the surrounding medium will give out oxygen. Animals and plants alike require oxygen for respiration, and in return give out carbon dioxide. If, therefore, the right proportion of animal and plant life can be established, the inter-relation as regards the exchange of gases is balanced and healthy conditions are ensured. The owner of the aquarium would do well to go to the pond, take note of the way in which plants grow, select a few suitable and healthy specimens, and transfer them directly to the aquarium.

American pond weed, starwort, or water crowfoot, are useful plants, which take root in the sand, and duckweed and frogbit float on the surface. (See "Living Creatures," chapter iii.) Several semi-aquatic plants may also be collected, especially for the breeding cases of dragon flies and caddis flies, which should show a combination of the aquarium

with terrestrial conditions. Of these plants watercress, mint, and forget-me-not thrive particularly well.

Having made our selection of good specimens of water plants, we must now give some attention to their arrangement in the aquarium. According to the kind of our tanks and vessels, three methods of planting "pond weed" may be noted.

1. For small aquaria—*e.g.*, jam jars—it is best to select a few short trails of water plants, tie the lower end of their stalks together and attach them to a stone. Care must be taken not to cut or bruise the stems in tying. To avoid this danger it is best to use some material like gardener's bast. Small strips of sheet lead are also useful. By means of them the stems can be clamped together and need not be fixed to a stone, as the lead itself will act as sinker. For æsthetic reasons it will be best to bury the stone or lead and the ends of the stems in the sand at the bottom of the jar.

2. We may secure some very small flower-pots, two or three inches in height, fill them with rich soil, and fix water plants in each. This may be done by actually imbedding the rootlets or by simply fixing the cut ends of the stalks in the earth, which in course of time induces roots to strike.

The soil in the pots should be covered with sand so that it cannot be washed out into the water and so discolour it. If the height of the tank allows it, sufficient sand might be deposited at the bottom to entirely cover the flower-pots, but if this reduces the space for free movement on the part of the animals, effect must be sacrificed and the pots must stand uncovered. This method of planting has been found specially useful in cases where the aquarium stands in a crowded classroom and there is no inflow or outflow of water at all. The plants grow extremely well, and yet there is not sufficient mould to produce the undesirable effects of putrefying organic matter that may occur when there is an insufficiency of oxygen in the water above the mud.

3. Large aquaria, and those that are either kept out of doors or have a constant flow of water, may be supplied with a layer of soil about two inches deep, and upon it a layer of sand, so that the water does not become muddy. In this "bed" the water weeds may be planted.

Whichever method of planting we adopt, it must be remembered that the aquarium should contain a fair supply of plants, but never so much as to hinder the creatures in their movements or to prevent the plants themselves from spreading out.

The tanks are now ready to be filled with water. On no account must a strong jet of water be applied, else all previous care in planting will be of no avail. It is best to lay a sheet of paper over the plants and sand, and to pour water upon this from a water-can provided with a "rose." When the tank is about half full the paper can be removed and the rest of the water can be poured in.

If the right amount of weed is supplied, the water in the aquarium is kept sweet and pure for a great length of time, and need not be changed. It may happen that a layer of green scum appears on the sides of the tanks, entirely screening the contents from view. This will have to be removed, and it may be done with the help of tadpoles and snails who browse on the green vegetation, or it can be removed with a pad of rag or a brush, but if, in consequence, the water becomes green and unsightly, it should be changed. Some aquaria—viz., those that contain snails and larvæ—need not be covered, while others containing newts and spiders must of necessity have some cover. The latter has the additional advantage of keeping the dust out. Pieces of glass are often used for this purpose, and if they are slightly raised from the rim of the tank by fastening tiny pieces of wood or cork on to the rim with the help of seccotine, so that air may be admitted, they are quite suitable. Jam jars and other small glass vessels can be covered with netting

stretched across the top with indiarubber bands. Other tanks are covered with pieces or lids of perforated zinc. In every case, although we ensure that the water is aerated by the water plants, we should be careful never to exclude air from outside entirely. In the case of most fishes and other lovers of very fresh water, other special means must be devised to ensure a liberal supply of air. The simplest way is to connect the tank with a water tap by means of a pipe, attaching to it a waste pipe at the bottom which will carry the water to a sink. But few of us are fortunate enough to have a tap and a sink at our disposal, and conveniently situated for our aquarium. We therefore make no attempt to keep animals that require fast-flowing water, and for those which need simply well-aired water we fit up a piece of apparatus as described in any textbook on aquaria.

The aquarium should now be allowed to become established—*i.e.*, the plants must take root, begin to grow, and adjust themselves to their new situation before animals are invited to take up their abode among them.

To the city-dwelling nature student, few animals provide more profitable study than the denizens of the pond, with their changeful lives. They are easily obtainable, their wants are few, and their curious habits and startling transformations keep a sympathetic observer in a constant state of astonishment and wonder. "What next?" said the tadpole, when his tail dropped off. "What next?" say we as skins are shed, as limbs appear, as organs disappear, as periods of death-like stillness are followed by seasons of intense aliveness, as babyhood, youth, and maturity follow in rapid succession, and the end of a spent life marks the beginning of a new one.

The question now arises, Which of these interesting creatures should we capture and keep, and how can we best provide for them?

The following animals have been found to thrive in captivity: newt, frog, toad, stickleback or minnow, caddis, dragonfly, water beetles, spiders, and snails. Some knowledge of their habits and life history may best be obtained from watching them carefully, and supplementing and verifying all observations by reference to some book on the subject.

When once we start pond dipping, the ancient instinct of hunting and the love of the chase often make themselves felt, and in our wild primitive joy we accumulate treasures we shall never be able to hoard. When we are in this mood we listen to no remonstrances. It is, therefore, with a sense of futility that we entreat the hunter to check his passion for the sake of all the creatures that will suffer and die for want of proper accommodation, and for the sake of those very regions of delight that would soon be depopulated and laid waste.

Let us assume that we have just been to some pond on the outskirts of our town, and have succeeded in catching all or some of the above creatures, partly by the help of a little net with a small bottle at the end, partly by drawing on to the bank portions of the floating masses of water weed, and searching it through with care. As many of these animals are distinctly beasts of prey, it is best to convey them home in separate bottles or tin boxes packed with wet weed. All these animals, except the fishes and tadpoles of frog, toad, and newt, can be kept out of water for a considerable length of time, and can therefore be conveniently put into tins whose weedy contents are kept wet. Before the pond is left, careful note should be taken of the general conditions in which the creatures have been living, so that they may be reproduced as exactly as possible.

If the directions are carried out, the aquarium is now ready for animal habitation. It stands to reason that if very small animals have been collected, they would soon be lost

sight of in a large tank; therefore minute organisms should be kept in aquaria made of tumblers, saucers, etc., and newts and fishes, large beetles, etc., must be given plenty of room for movement. Experience will teach best which animals can be kept together, but in order to prevent much unnecessary loss of life, a few suggestions may be supplied to the beginner, which he can modify or reject as he gains wisdom by experience.

A word must be said on the subject of homes for frogs, toads, and newts, which live both on land and in water, though space does not permit to discuss the construction of vivaria. A low wooden box, partly filled with earth and living turf, and furnished with a large shallow, preferably glass or brown earthenware dish, with water plants, is one of the simplest and cheapest forms, and answers the purpose well.

It is well to remember that a few animals in each aquarium will be a source of interest and lasting pleasure, whereas an overstocked tank has "struggle" and "discord" written all over it. The following are some groups of animals which can be kept in the same aquarium, provided that they are liberally supplied with food, otherwise the strong will attack the weak in their effort for self-preservation.

(*a*) Newts, caddises, snails.
(*b*) Caddises, dragonfly larvæ and trumpet snails.
(*c*) Carnivorous water beetles and ramshorn snails.
(*d*) Silver beetles, fishes, snails.
(*e*) Tadpoles, caddises, snails.
(*f*) Newts, fishes, snails.

It is best to keep silver spiders and larvæ of the carnivorous beetle quite by themselves. The obvious reason why we make some selection of animals that we keep together is that many are beasts of prey and would kill the others. It is true that they are together in the pond, but they have far more numerous means of escape and hiding in the

pond than in our little tanks. But let us look at this question of "preying upon one another" in another light. It is not the uncontrolled elemental love of the chase only, but rather the still more primeval factor of life which lies at the root of hunting—hunger. This being an element in the very life of the creatures in which we are specially interested, we cannot ignore it in our righteous indignation against the taking of life, nor can we entirely alter the state of things, and educate newts and frogs to eat little pieces of raw meat, concerning the source of which we ask no indiscreet questions. The following remarks will be devoted to the subject of food for the different animals mentioned.

Newts.—Although newts must be supplied with plenty of weeds reaching to the surface of the water, so that they can rest with their noses out of the water if they feel inclined, it is quite a mistake to imagine that the plants serve them as food. They eat no vegetable matter, and must be supplied with small worms or tadpoles, preferably the former; small earthworms, "red worms," bloodworms, and gentles are all suitable, and to the city dweller be it said that these may be obtained cheaply from any livestock dealer who keeps fishes and aquaria. A pennyworth of "red worms" will go a long way, and any not immediately required can be kept in damp earth in a jar. Occasionally a newt will take a shred of raw meat if presented to it at the end of a straightened-out hairpin, which is kept in motion. Perhaps with great care, patience, and expenditure of time, this form of feeding may be adopted.

Frogs.—These creatures should not be fed while in the water, or even in their vivarium, but should be taken out and placed in a biscuit tin, into which worms, smooth caterpillars, or gentles have been put.

The lid may be put lightly on the box, so that in the dusk they may feel at ease. After some time, when we are satisfied on the subject of their appetites, we can remove

them into their home. The same process of feeding holds for toads. Both frogs and newts should be liberally supplied with food every two or three days, and should have occasional morsels put into their tanks and cases between these regular meals. Tadpoles nibble delicate plants, and occasionally they should be given a small piece of raw meat.

Sticklebacks and **minnows** should be fed every day with "bloodworms" or *shreds of raw meat. No bread should* ever be given to them.

Caddis worms are vegetarians, and want plenty of a variety of water plants, both for the building of their homes and for food. By their voracious feeding they often destroy the pretty appearance of our aquaria, as they ruthlessly bite off the water plants, but this cannot be helped. Watercress bought off a barrow, and held in position with some of the leaves above water, as before indicated, forms convenient material when we run short of pond weed. An occasional piece of raw meat is greedily devoured.

Dragonfly larvæ, if the larger species, are best supplied with bloodworms, and should be fed daily. The small species, with the long slender body and three leaf-like appendages at the end, also eat small bloodworms, but pond water, containing water fleas and other minute organisms, should be poured into their tank from a "stock pot" filled at the last pond-hunting excursion.

Water Beetles.—The carnivorous beetle must, of necessity, be supplied with meat foods; worms and tadpoles are greedily devoured, but it thrives well on pieces of raw meat, which should be given to it daily. The much larger silver beetle, on the other hand, is a strict vegetarian, and browses on the leaves of starwort and almost any other pond weed.

Silver spiders are a source of some anxiety to the humane aquarium keeper. Normally they live upon the innumerable larvæ and other small creatures that drift and swim in the

water, but unless we have access to a pond these wants cannot easily be supplied, as these little larvæ do not live well in the "stock pot." The spiders have been seen to make a meal of "bloodworms" and water hog-lice, but they give one the impression that they eat these dainties because there is nothing else. The fact that they live for weeks without any food at all relieves the unscrupulous aquarium keeper from the worry of finding suitable food for them.

Snails are most easily kept, because they live upon dead and living vegetable matter, and many act as scavengers and clear up the refuse of other creatures.

(Detailed information regarding plants and animals of the aquarium will be found in "Living Creatures.")

IV. THE EXPERIMENTAL STUDY OF BREATHING AND FEEDING IN PLANTS

The General Argument for the Practical Study of these Functions

Seeds have been sown, and some have germinated and others have not grown at all. When the latter were examined, they were found to show signs of decomposition, and they were spoken of as being dead. In the course of all the weeks of work in growing seeds, many seeds attained a certain stage of development and then faded; they were spoken of as having died. By such statements, it is implied that the growing seedlings are alive. They grow, changing their form as they do so and developing new parts. They use up the water, hence they drink, and it is generally believed that they take nourishing material first out of the cotyledons and then out of the soil, but of this the seed experiments have not provided us definite evidence. The seedlings responded in various ways to their surroundings; they grew

tall and pale in the dark, they remained short and green in the light, and they produced a great number of root hairs when moisture was scarce and much fewer when it was plentiful. The pea seedlings took hold of trellis work, supporting their thin and feeble stems. Rootlets grew right over and downward if the seed was planted upside down, but they grew directly downwards if the seed was planted with the radicle downwards. All these facts suggest behaviour as we know it in animals and confirm the general impression that plants are alive. It would be of interest if we could find evidence of life in plants. We have seen with our eyes that they have a rhythmic existence even as animals have. From infancy onwards they grow with increasing vitality, a period of fruiting and reproduction follows, and then rest or decline, and offsprings start a fresh cycle. We have seen with our own eyes that birth and death punctuate the rhythm; that plants grow differently according to conditions, yet preserve the general plan or pattern of the family to which they belong. All these characteristics are signs of aliveness, but it is with regard to the fundamental necessities of breathing and feeding that we have no definite evidence. Consequently, our assumption of life in plants rests on insecure foundations.

It is not possible to sit down by our oak seedling and watch its breathing in the manner that we can watch the sleeping puppy on the hearthrug, nor can we make observations how the sunflower seedling consumes its daily meals. Very subtle ways and means involving the use of laboratory apparatus have to be devised before these signs of life in plants can be witnessed. In many schools there is neither the necessary laboratory equipment available nor the specialized skill in the use of apparatus to furnish proofs in the study of plant life, but it is possible to make use of simple experiments which illustrate in a concrete and practical way the method of biological investigation and argument.

Such method of procedure will ensure intelligent grasp on the part of the class of certain facts of plant life, and at the same time an insight into scientific method.

Breathing of Plants

In order to ascertain whether the breathing of plants is similar to that of animals, it is necessary to gather together all the facts known to us which concern the breathing of animals (including our own). We know (*a*) that air is drawn in by bodily movement; (*b*) that air is expelled also by bodily movement; (*c*) that air given out is warm and moist; (*d*) that the air given out cannot be the same in composition as the air given in, because closed rooms in which many people have breathed become stuffy and the air may even become poisonous. The air must have undergone some change in the lungs before it is breathed out again. We cannot perceive the change either by smell or sight, but chemists can easily detect air that has been changed by respiration. They use lime water, which is quite clear, like ordinary water, and it quickly indicates the presence of exhaled air. How? See for yourself.

Experiment I.—Pour a little lime water into a tumbler or test tube. Gently blow into the lime water through a piece of glass tubing a few inches long. The clear lime water turns milky. We know now how breath can be detected, and will try with our germinating seeds.

Experiment II.—Some seeds are soaked for twenty-four hours, and are allowed to germinate. Take a jar which can be closed with a well-fitting cork. By means of a bent hairpin fix a hook into the cork and suspend from it a little bag of netting containing the germinating seeds. Pour a little lime water into the jar. It will be found that in the course of time the lime water becomes milky. The experiment will be more convincing if two jars are used. In one case the jar is filled with moist sawdust, and the other with

seeds. It will be found that only the latter becomes milky. The milkiness is, therefore, due to the seeds and the seeds only.

The experiment can be varied. Instead of seeds, flowers may be used. Green leaves may be put into a tin with a small jar of lime water and the lid of the tin closed. In each case the same result will be noticed. A puzzling result will be obtained if a growing plant or a spray of leaves in a bottle of water is put into a large glass jar or under a bell jar, together with a beaker of lime water, and the whole apparatus is kept on the window-sill. Reference will be made to this later.

It appears from the general results of these experiments that seed breath is the same as animal breath, and our assumption that plants, since they breathe, are alive, seems correct. It would, however, be of interest to know more about the process of breathing, and to see what it means in the life of animals and plants.

There is another phenomenon which we associate in our thoughts with aliveness. We speak of the "leaping" and "living" flame, the "live" coal, the fire in the range "choked with ashes." It would be well to look into the matter and see how far we are justified in thinking of flames as alive. We shall treat a candle flame in the same way as the growing seeds and see whether lime water will become milky.

Experiment III.—Take a glass jar and find a cork to fit it. You also require a smaller cork and a short piece of candle. Pass a piece of wire through the centre of the two corks. Arrange them so that the small cork is attached to one end of the wire and is passed into the jar, having the candle fixed to it on its upper surface. Pour a little lime water into the jar. Now light the candle and close the mouth of the jar with the large cork, and note what happens. The inside of the jar becomes dim, the candle goes out, and the lime water turns milky.

It is evident that the candle flame also makes the air impossible to use, and consequently it goes out. Like our breath the burning makes the air moist, and like breathing the process of burning causes lime water to become milky. The scientific name of the gas which breath contains and which makes lime water milky is carbon dioxide. It is always present in the air, but in very small quantities (about 0·04 per cent.). Considering the countless hosts of living creatures, animals, and plants, and all the burning fires, it is difficult to understand that there should be so little carbon dioxide in the air, and that the proportion does not increase daily and rapidly. We shall be able to explain this wonder later.

The question now arises, whether in breathing plants merely add carbon dioxide to the air which they have taken in or whether they use up part of the air. The following experiment will help us to come to some decision.

Experiment IV.—Find a bottle with a narrow neck, fitted with a stopper. A hole must be bored through the stopper so that a piece of glass tubing can be passed through it, projecting one to two inches beyond the cork. Care must be taken that the stopper and glass tube fit well. Into the bottle place a quantity of soaked peas or other seeds. The bottle will have to be inverted; it may, therefore, be well to push a little piece of wire gauze into the neck of the bottle to prevent the seeds from falling into the neck. Before the stopper is inserted, a piece of caustic potash about one inch in length is laid upon it; the lower end of the tube is made to dip into a bottle containing water. A few drops of red ink in the water make the experiment more effective. By means of a retort stand and clamp the apparatus is supported in an upright position. In the course of a few days the coloured water will be seen to rise in the tube.

What is the meaning of the apparatus, and what can we learn from the experiment ?

The germinating seeds are enclosed in a given amount of air. In this they will live and grow for a certain length of time, giving out carbon dioxide in breathing. Chemists have found that the substance caustic potash absorbs carbon dioxide, so that by placing a piece of the substance into the bottle, the breath gas is removed, and the remaining gas can be examined. Why does the water rise in the tube? Clearly the flask is gradually getting less full of air, and the water can now rise up in the tube. A very intelligent pupil will point out that the air containing carbon dioxide will become diminished when the latter is absorbed by the caustic potash—therefore, water will rise whether there are seeds in the flask or not. We have to bear in mind, however, that so small a trace of carbon dioxide would cause a proportionately small rise of water in the tube, whereas the increase in the height of the column of water is very considerable. The seedlings have, therefore, used up a considerable amount of air.

It will be found that at no time will the water fill the whole of the flask. When a certain level is reached, it will stop rising, and after that it will actually sink, the seeds showing signs of death and decomposition. If a burning taper or splinter of wood were put into the flask when the water had ceased rising, it would be found that the flame went out. The fact that the seeds began to die and the flame goes out, although there is no carbon dioxide present, shows that the remaining air cannot be the same as the air of the atmosphere.

As a matter of fact, the air consists of two gases, nitrogen and oxygen, of which the former is inert and the latter very active. It is the latter which is used by the living body and the burning flame, with the result that carbon dioxide is given out. Of course, this exchange of gases between the plants and the air is not in itself important, but it is the result of an extremely important process that goes on in the

body of the plant; just as in our fireplace it is not of great importance that air, containing oxygen, should be drawn in under the grate, and that carbon dioxide should escape from the chimney. What is important is that oxygen should combine with wood or coal in giving out heat and light. It is the same with plants. The oxygen in the air combines with substances which their body contains, and heat is also evolved. The giving out of heat always implies energy—that is, the power of doing work.

We now see that all forms of activity and behaviour for which the children have loved the seeds are manifestations of vital energy, which energy becomes available for work when the plant breathes and the oxygen enters into combination with carbon contained in the substance of the tissues.

It may, of course, be argued that we can hardly call respiration a process of combustion, when there is no evidence of heat. It is quite true that the body of plants does not feel warm to us, but by means of a sensitive instrument and proper conditions, heat could nevertheless be detected.

Experiment V.—Obtain two large jam-jars and enough barley, oat, or wheat seed to fill them both. Soak the seed for twenty-four hours. Boil half the seed for a few minutes. Drain both quantities of seed and fill one jar with each kind. Place each jar upon a plate and cover with a bell jar. Through the neck of each bell jar pass a thermometer, pushing the bulb deeply into the seed. Plug the neck of the bell jar with cotton-wool. Place the jars near together and allow some time to elapse before reading the thermometer. Take a series of readings at intervals and put them down in the form of a table. Take the jars to a colder or warmer place and take more readings.

It will be found that the living and germinating grain has a higher temperature than the dead grain. We realize, therefore, that the process of burning in plants is so slight that heat can hardly be detected. In animals, the process

is much more vigorous, but most vigorous of all when a fire is burning.

The question may be raised whether the fire should be counted among living things, but considering the situation carefully, we realize that the process of combustion is all that it has in common with living things. The fire has no body with organs that have definite functions. It does not grow and change in a definite rhythm. It has no fruiting time and no offsprings. It cannot obtain its own food and does not in any way behave so as to benefit itself.

Food of Plants

Chemical Composition of Plants.—In the course of the work with seeds acquaintance has been made with a large variety of seeds. Pea, bean, sunflower, nasturtium, mustard, cress, onion, cereals, marrow, are all well known. Seeds and seedlings of many trees have also found their way into the classroom. If all the oak, beech, and fir seed had been actually sown, in fifty years' time the timber obtained from them would take up many waggon-loads. The weight of the seeds would have immeasurably increased—just by growing. This miracle can only be explained when we recognize the fact that during the whole time of their existence new substances have been added to the substance of the seeds, day by day, year by year. The substances added constitute the food material of the plant that are built up and incorporated in its tissues in the process of growth. What are the substances that constitute the food material ?

It is easy to understand that whatever the food materials may be, they would not be found in the course of the most minute examination of the body of the plant, any more than the bread we eat forms, as such, part of our body. But the chemical substances of which the tissues of our body are composed have formed constituent parts of our food. So it is with plants. Of what does a plant consist ?

Water certainly forms part of the plant. If any root stem or leaf is crushed, moisture becomes evident. It would be interesting to know what proportion of the body of a plant is water.

It seems very easy to determine this. A quantity of plant material is weighed, dried, and weighed again. In reality the investigation is not quite so simple. How can we know that at the time of the second weighing the plant material really contains no more water? Perhaps, if the process of drying had been continued, further loss of water would have occurred. It is actually necessary to weigh repeatedly until for two or three successive weighings there is no change in weight. Even then the result is not entirely accurate. By altering or intensifying the method of drying there might be further loss of weight. However, for our present purpose we shall be satisfied with a rough method of investigation.

Experiment I.—Cut cubes of apple, potato, carrot, etc., and various pieces of leaves. Weigh each. Dry the specimens in a laboratory drying oven, if there is one available. If not, dry in a warm airy place. It will take much longer, but the result may be to some degree more accurate.

By such experimentation we find that some plants or parts of plants consist of 90 or 95 parts of water in every 100 parts by weight of plant substance.

Of what does the dry part of the plant consist?

We remind ourselves of certain accidents in the kitchen. An apple tart was forgotten in the hot oven. It was burnt quite black. The black crust tasted very bitter. Some parts were very brittle and glistening, and tasted of nothing at all; they were the most completely burnt. The apple tart consisted almost entirely of plant substance. We know that in heating the water escaped; perhaps some other substances escaped with it in the form of gas, but certainly the black charred substance has remained. It is, in fact,

a form of charcoal. Charcoal is obtained from wood, a plant substance, which is burnt in an insufficient supply of air. This is exactly what happened to the apple tart in the oven.

Experiment II.—If a Bunsen burner is available, heat in a hard glass test-tube a small piece of wood or any other plant substance and watch it change from stage to stage till charcoal is obtained. The experiment can be done at home by using any little tin made of one piece instead of the glass tube, putting the lid on lightly and laying it on glowing coals.

Charcoal is largely composed of carbon. If the chemist were asked what carbon was, he would say carbon is carbon, just as copper is copper. It cannot be separated into any other substance. It is, in fact, an *element.* We should find pure carbon in the form of soot in the chimney.

It is, however, not the pure carbon which interests us most at the present moment, but the impurities in the charcoal, since they constitute the other elements of which the plant is composed. How can they be obtained?

We make use of the fact that charcoal can be completely burnt up, provided there is sufficient air.

Experiment III.—Taking the charred material obtained in Experiment II., put it on an open tin on the burner or coal fire till it is burnt away. There will be a little white ash left which will change no further. We do not know what this ash is, whether it, too, is an element or whether it can be split up further. We have reached the limit of our possibilities in chemical analysis under existing classroom conditions. We can, however, now understand what such analysis means. All the same it is difficult to believe the chemists' assertion that the little white ash may contain a large number of different solid elements such as sulphur, phosphorus, calcium, magnesium, iron, iodine, and many others. Is it to contain sulphur when it does not burn,

iodine when it does not smell, iron when we can see no gleaming metal? The following experiment may help us to understand and believe.

Experiment IV.—Obtain a few pieces of granulated zinc. Pour a very small quantity of dilute hydrochloric acid into a glass (beaker). Drop one piece of zinc after another into the acid. The fizzing of the liquid means that gas is escaping. When this is going on much more slowly, put in a few more pieces and leave the glass standing until the next day. Gently pour off the clear liquid into a china basin and heat it. It will become thick like syrup. Take it from the flame and leave it to cool. It will become a solid which can be broken up and powdered. It is now quite unlike the zinc with which we started. It has entered into combination with part of the acid, and this compound has qualities quite *different from those of the original zinc.*

Sugar is such a chemical compound consisting of carbon and water, yet unlike both these constituents. Similarly table salt consists of a substance (sodium) which would have a deadly effect if we consumed it, and of a gas (chlorine) which it would be fatal to breathe—yet the two in combination (not mixed together) constitute the white crystalline substance which forms part of our necessary food.

Thus the plant ash does not contain the various elements in pure form, but in combination with each other.

We now understand that the food material of plants must consist at least of water and carbon as well as of a number of chemical substances which constitute plant ash. We also bear in mind that certain ingredients may have escaped into the air as gases when the plant substance was heated and burnt. Before enquiring into the manner in which these food materials can be obtained and finding out from what sources they come, we may note how they are used. We have examined the plant tissues, and in analyzing them we have found the substances; it is, therefore, reasonable

to assume that the substances go to build up the tissues just as the animal food goes to build up the animal body. But some facts, known to us, must come into our biological consideration.

1. We have studied the process of breathing and have understood that this is a form of combustion yielding energy for all activities of animals and plants. Combustion implies fuel. This fuel contained within the tissues of the plant must, as the tissues themselves, be derived from the food of the plant.

2. When seeds were studied, the condition of the cotyledons (seed leaves) was specially noticed. They are very fleshy leaves, and as the seedling grows they become thinner. In the same way the grain of wheat or other cereal becomes soft and finally nearly empty as the seedling grows. In both cases the seed contains food on which the baby plant subsists until it can procure its own nourishment.

Again, if a potato is kept in a dark, moist place, it will make many shoots, may even form little new potatoes, yet, besides water, it was not supplied with any food material. The old potato will become limp and shrivelled; all the food stored in its tissues has gone to form shoots and new potatoes.

Lastly, when we planted bulbs in the autumn, leaves and flowers grew and unfolded long before any plants grown from seeds could have produced flowering shoots. The explanation was that the fleshy scales and stems characteristic of bulbs and corms contained so large a store of food that the plant could live on this legacy and grow at its expense.

We have some knowledge of these food stores in plants, because they serve us and other animals too. We know that potato contains starch. We know that bread is made from flour, also largely starch, and that this starch is obtained from wheat and other cereals. We do not eat tulip and hyacinth bulbs, but their near relative, the onion, is a valuable food plant. Its substance tastes so sweet that we

rightly suspect the presence of sugar. This suggests other sweet plant tissues—carrots, bananas, and many nuts. In the latter we find fat in the form of oil; we need only crush a nut kernel between two pieces of clean white paper and there can be no doubt about this.

Starch, sugar, fat—the very substances that we need for food, the plants also use for food—here is another sign of kinship between plants and animals in the world of living things. Starch, sugar, and fat are all made of carbon in different proportions, and of oxygen and hydrogen, which are the constituents of water. We therefore see that the raw material carbon and water, which we have already discussed, are elaborated into the foodstuffs starch, sugar, and fat. Another very important class of foodstuffs found in plants have, in addition to the three elements, nitrogen in their composition. These foodstuffs are called proteins. Peas, beans, nuts, and other seeds contain proteins.

Would it be possible to examine parts of different plants and find out whether they contain starch, sugar, etc.? The process requires more experience in chemistry and better laboratory equipment than we have at our disposal, but we have already mentioned how sugar and fat, if present in considerable quantity, may be detected in a rough-and-ready way. Starch is much easier to discover than protein, and as the searching for starch will be useful for later work and will, at the same time, give an insight into the chemist's method of investigation, the way of searching may be described.

Starch has the peculiarity of turning blue, violet, or black, according to circumstances, if it is brought into contact with a solution of iodine (iodine dissolved in a solution of potassium iodide to the colour of dark beer). If we put a drop of this solution upon bread, potato, flour, etc., the colour will be violet or black. If we prepare some thin starch by mixing laundry starch with boiling water and

add iodine to a small portion of it, a blue colour will be obtained. It will now be possible to test various parts of plants.

The green colouring matter will be very much in the way if we work with leaves and stems, and it will make the judging of colour very difficult. We can go one step further in our experimental work and apply Sach's iodine test. Lay some fresh leaves or stems into boiling water for a few minutes. Heat some methylated spirit in a beaker standing in a water-bath and put the leaves into it. Great care must be taken to keep the flame low and away from the methylated spirit vapour, as the latter is very inflammable. The green colour will readily come out of the leaves and they will become quite pale. They can then be treated with iodine and will show the characteristic dark violet colour if they contain starch. It would be interesting to try the experiment with some leaves freshly gathered and with some stale leaves.

Of all the foodstuffs mentioned starch is the most common one; therefore the finding of starch will be practically useful. We have now seen that the food materials, water, carbon, and the elements that are contained in the ash and any gases that have escaped in burning, are built up into the foodstuffs, starch, sugar, fat, and protein, upon which the plant lives, and which are used in growth and repair of tissues, as well as in respiration.

It will next be our business to discuss the source from which plants obtain their food materials. In other words, we must know what they feed upon. The food supply must be derived from the soil or rain-water or air, or from more than one of these factors of its environment, because the plant has access to nothing else.

There are many kinds of plants which live in the water. Some have no roots and simply float, forming green slime or tangled masses of stems and small leaves. These plants

must get all they want from the water. After all, ordinary plants whose roots are in the soil cannot take in any solid particles of earth; they, too, must have liquid food. If, therefore, they obtain their food materials from the soil, it can be only such substances as will dissolve in the percolating rain-water either naturally or because the plant has rendered them soluble. It should, therefore, be possible to grow any plant in water if the right soil substances are dissolved in it. If we knew the prescription, we might save the seedlings which we have previously tried to grow in water, by adding to the latter the right ingredients.

After experimenting with many different solutions, botanists now know several prescriptions for food solutions in which plants thrive. Plants require the following elements: oxygen, hydrogen (which together form water), carbon, nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron. A few others, such as sodium and chlorine, are necessary to some plants and useful to most. The following prescription for a food solution is easily carried out. If no laboratory materials are available, a chemist could make up the prescription.

1 litre distilled water or filtered rainwater. If neither is obtainable ordinary tap-water can be used.
1 gramme calcium nitrate $Ca(NO_3)_2$
·25 grammes potassium chloride (KCl)
·25 grammes magnesium sulphate ($MgSO_4$)
·25 grammes potassium phosphate (KH_2PO_4)
A few drops of iron perchloride solution ($FeCl_3$)

If circumstances permit, it is advisable to prepare 2 to 4 times this quantity and use very large jars, such as Winchester bottles, 7-lb. jam jars, etc. Satisfactory results have, however, been obtained with much smaller jars, such as 3-lb. jam jars. If a wide-mouthed jar is used, a cork or circular piece of wood must be found to fit it. This has a hole in the middle and is cut across the centre into two parts. The seedling of bean, maize, or acorn is fixed by means

of cotton-wool into the middle in such a way that the rootlet 1 to 2 inches in length dips into the solution. The seed or cotyledons are in the moist air under the cork and over the water, and the shoot growing up through the cork. If a narrow-necked bottle is used, cotton-wool only is required to hold the seedling in position. The sides of the jar must be covered with black paper to keep out the light, else green scum will grow on the glass and the rootlets. Over the black paper white paper should be wrapped if the jars are to stand in sunny places. This will prevent the jars from becoming warm.

Instead of cork, a piece of netting or muslin can be tied over the jar and the seedling so arranged that the rootlet passes through a hole into the solution, but care must be taken to prevent dust from falling through the netting into the solution.

The whole apparatus must be placed on a window-sill allowing the plant as much light as possible. Water which has evaporated must be replaced, and if the plant is provided with entirely fresh solution about once a month, a greater measure of success is ensured. About once a week air should be pumped (not blown) into the water, for which purpose a bicycle pump or pair of bellows should be used. The solution should be kept very slightly acid. It can be tested by a strip of blue litmus paper. If it becomes slightly pink, the solution is in good condition, otherwise a few drops of dilute nitric acid must be added. It is important that the seedlings to be used are very healthy and clean. Soak about ten maize or bean seeds in distilled or rain-water for about twelve hours. Mix some sawdust with distilled water, rub it between your hands, letting it fall lightly into a flower-pot to a height of two-thirds of the pot. Lay the soaked seeds upon the sawdust and fill the pot. Put a saucer or glass plate over the top, and the seeds will germinate in the course of some days.

In our eagerness to make up a solution of nutrient salts for our much-beloved seedlings, whereby we might save their lives, we are at this stage and age apt to be in no way critical. But when the excitement of new expectations is over, and we stand by to wait and see, our critical faculty asserts itself and we look through our prescription again. Will it really be possible to rear our bean from seedling to flower and fruit on water and a few salts dissolved in very small quantities ? It seems incredible. It is incredible because we have just studied the names of the chemical compounds in the solution and compared them with the names of the ten necessary elements in the constitution of the plant, and we note that one—viz., carbon—has been omitted. Sometimes more than half the weight of plants, after the water has been evaporated, consists of carbon, and this substance has been omitted. If it has been omitted, it must mean that plants do not obtain their supply of carbon from the soil. Where else can they obtain it ? Could it be from the air ?

We refer back to our notes on the breathing of plants and remind ourselves that animals and plants, candle flames, coal and wood fires, all yield carbon dioxide—gas containing carbon—and this escapes into the air. We raised the question then (p. 84) how it could be possible that the carbon dioxide in the air could remain small in amount and constant in proportion. Could it be that plants use the carbon in the air in the manufacture of their starch and sugar and fat and protein ? If half the dry weight of plants consist of carbon, think of the enormous amount of carbon dioxide that must be consumed by a single green field, a single potato patch, a single forest. It is worth while to see by practical experiment how far this inference is correct. Even with elementary knowledge and limited opportunity, profitable investigation may be carried out. It should first be determined whether a plant can make starch, even if it is provided with air from which carbon dioxide has been removed. If it

cannot do so, it seems evident that the carbon dioxide in the air must be the source of supply of the necessary carbon.

We have already learnt how to detect starch in plant tissues. We also know how to deprive air of carbon dioxide by means of caustic potash. It is, therefore, easy to plan an experiment which will show whether plants can make starch in the absence of carbon dioxide. A great difficulty, however, presents itself on further reflection. Supposing we find starch in the leaves or stems, what evidence have we that such starch has been elaborated in the absence of carbon dioxide and has not existed in the plant before the experiment was attempted ?

Since the building up of starch is an elaborate piece of work, it seems probable that the process is not continuous, but that the plant has periods of rest and periods in which any manufactured starch is used up. If we could gather a leaf from a plant very early in the morning, another in the middle of the day, another after sunset, and subject each to the iodine test, we might find a period in which the leaf was without starch. This has actually been done repeatedly with satisfactory results.

Experiment V.—Take a healthy plant of nasturtium or geranium, growing in a pot. At the end of a bright day, remove a leaf from it and test it with iodine. Put the plant in a dark place, so that without getting up too early you can pick another leaf still in the night condition. Test this leaf also for starch. The experiment may be varied, and a plant growing in the garden studied. Again taking a leaf in bright daylight, it is treated with iodine, while another leaf is covered with black paper on both sides, is left till the next day, and then tested. If the whole process of the iodine test is too elaborate, mix a little sulphurous ether with the iodine. This will make the iodine penetrate more easily into the leaf. Paint with this a portion of the underside of the leaves without first extracting the chlorophyll. If

there is starch present, the painted parts become deep indigo colour; if no starch is present, they become greenish-brown in colour.

From these experiments we learn that starch is only made in daylight. Similarly, it has been found that only green leaves can manufacture starch. Experiment with variegated leaves, leaves of seedlings grown in the dark, etc.

We can now return to our original enquiry—do plants use the carbon dioxide of the air for the supply of carbon necessary for the production of starch ?

Experiment VI.—A small plant of fuchsia, geranium, or nasturtium, growing in a pot, must be kept in the dark for one or two days, so that no starch remains in the leaves, all of it having been used up. Place it upon a non-porous china saucer or glass dish and stand the whole into a larger dish. Place a bell jar over the pot and saucer and inside the larger dish. Caustic potash or caustic soda solution is poured into the large dish, care being taken that it does not flow into the saucer. In the neck (tubulus) of the bell jar fit with plasticine one or two pieces of bent glass tubing. Place some soda lime into the bend of each tube. This also absorbs carbon dioxide, but is used in this case because it is a solid in small particles and thus allows air to pass into the bell jar. In this way the plant will be surrounded by air, but the latter will not contain carbon dioxide. Place the apparatus in a good light and test a leaf for starch after a few days. It will be clear that no starch is produced in the absence of carbon dioxide.

This conclusion can be confirmed by means of a further experiment. If the carbon which is necessary for the starch is obtained from the carbon dioxide of the air, what becomes of the oxygen with which the carbon is combined ? Is it given back into the air ? Whether this is so would be difficult to determine, as the atmosphere is a mixture of nitrogen and oxygen, and a little whiff of oxygen from a plant

could never be discovered. We shall have to work with plants in a medium which does not contain free oxygen. We can arrange the experiment with water plants.

Experiment VII.—Put some trails of water plants such as American pond weed into a clear glass bottle and fill it entirely with fresh tap-water. Put your finger over the mouth of the bottle and invert it over a jar of water in such a way that no air space appears in the bottle. Keep the apparatus in a good light for several days. Water plants also take in carbon dioxide, but they take it from the water in which it is dissolved. The water also contains air in solution, which means that oxygen is already present. The water is saturated with air and can hold no more. Therefore, if the plant gives out oxygen, the latter will rise to the top of the inverted bottle, and gradually displace some of the water. We can accept it that the gas is really oxygen, but it is still more interesting to test it. We bear in mind that oxygen is necessary for burning and that in the air it is very much diluted with nitrogen. If a splinter of wood or a taper no longer burns, but still glimmers, it will burn up brightly in oxygen.

Experiment VIII.—Raise the neck of the bottle containing the water plants near to the surface of the water, place your finger firmly upon it, take it out of the water, place it upright on the table, remove the finger and instantly plunge a glowing splinter into the space filled with gas. The bright flame will not leave anyone in doubt as to the fact that the plants have given out oxygen.

The importance of these facts of plant life may now be realized. Enormous quantities of oxygen are used from the air by all the breathing animals and plants and by all the burning fires, which on the other hand give out carbon dioxide into the air. Plants, in the course of a process called carbon assimilation, or better, photo-synthesis, make use of the carbon dioxide in the manufacture of their own

food, retaining carbon and setting free oxygen. The oxygen becomes now available for their own breathing and that of all living things as well as for the burning of fuel. Thus there is an eternal cycle of oxygen and carbon dioxide between animals and plants which constitute the balance of nature. If we have the right proportion of animal and plant life in our aquaria, we could seal a cover over the tanks, knowing that all the oxygen required by plants and animals for breathing would be produced by the plants, and all the carbon dioxide that the latter needs for food production would be obtained from the breath of animals and plants.

There is yet another relationship to which reference must be made. We have spoken of the power of doing work which comes direct from the combination of oxygen used in breathing with substances in the tissues. These substances are directly or indirectly sugars, starches, fats, and proteins. In combustion they are broken up, and one of the products is carbon dioxide. From what source are these substances obtained? Here we come face to face with a great difference between the feeding of animals and plants. Animals derive their food substances from the plants they eat. If they happen to live on animal food, their nutritive connection with plants is only a little further removed, but is just as real. If a lion feeds on antelopes and the latter on grass, the lion's body possesses the necessary starch, sugar, fat, proteid, which the antelope in the first instance obtained from the grass. No animal body can achieve what plants can do—viz., take in carbon dioxide, use from it the carbon, which at once combines with water, forming first a kind of sugar and then starch. More complicated substances, such as proteins, imply the use of some of the substances, certainly nitrogen compounds, which the water contains in solution. We find thus that plants can manufacture the food necessary to provide the energy for their own movement,

growth, repair, and reproduction, as well as for the activities of the animals. Plants can store energy in the food they elaborate, and plants and animals can release it in breathing and use it in work.

We must be clear at this stage where the energy comes from which plants store in their foodstuffs. Only in sunlight, we have learnt, can plants make starch. Without light, carbon dioxide is not split up into carbon for the making of sugar and starch, nor is oxygen given out. It would be easy at this stage to make further and more accurate experiments to provide evidence in support of this. We now understand that the plant obtains from the sun energy in the form of light, and this is utilized in the building of foodstuffs. All energy that living things display is thus sunshine captured by the plants. Out of earth and water, air and sunshine, are all living things made.

We next ask ourselves by what means can plants trap sunlight. This process is extremely complex and difficult to understand. But this much seems clear, that carbon dioxide together with the green colour of plants alone can give rise to sugar and starch. In the course of the iodine test which we have practised repeatedly, we have extracted the green colour from leaves and have obtained a solution of it in alcohol. It exists in the cells of which the leaves are composed. If a microscope is available, it may be seen in the form of little grains in the little leaves of mosses, which are very thin and transparent. It is the possession of these little chlorophyll grains that ensures the power of utilizing the sun's energy.

Can chemists in their laboratories build up sugar and starch from carbon dioxide and water? They have only gone part of the way.

BIBLIOGRAPHY

THE School Nature Study Union (Secretary, Mr. Turner, 1, Grosvenor Park, Camberwell, S.E.) has published a list of books which are recommended for nature study. It is a comprehensive and classified list, comprising works of reference as well as elementary and less specialised books.

For the beginner in teaching nature study on the lines suggested in these pages the following books would be found useful:

Nature Study Leaflets. Published by the School Nature Study Union.

Flowers of the Field. By Johns. Price 12s. 6d. (Routledge.)

Junior Botany. By T. W. Woodhead. Price 3s. 6d. (Clarendon Press.)

An Introduction to the Study of Plants. By F. E. Fritsch and E. J. Salisbury. Price 7s. 6d. (Bell.)

The Aims and Methods of Nature Study. By J. Rennie. Price 5s. (University Tutorial Press.)

The Biology of the Seasons. By J. A. Thomson. Price 15s. (Melrose.)

Introduction to Zoology through Nature Study. By R. B. Lulham. Price 10s. (Macmillan.)

Living Creatures. By C. von Wyss. Price 12s. 6d. (Black.)